1. TROPICAL METEOROLOGY OF CENTRAL AMERICA

1.1 General Introduction

This Handbook describes the analysis and forecasting of both atmospheric and oceanic conditions important to air/sea operations over Central America and adjacent waters.

Central America, as addressed in this handbook, includes the following seven nations, commencing with the nation located farthest west: Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica and Panama (Figs. 1.1, 1.2).

Central America, lying between 7°N and 19°N, has its weather primarily influenced by features carried by the low-level "easterlies"[1] for most of the year, yet it is susceptible to the penetration of cold fronts (shear lines or "Atemporalados"[2]) during the Northern Hemisphere winter. While the time of the "rainy season" cannot be generalized for all of Central America, Portig (1976) depicts the rainy season for the North Pacific portion of Central America from about May through October, while it is a month later for the North Atlantic portion, i.e., from about June through November—despite appreciable rain in December.

While the threat of tropical storms or hurricanes is small, it cannot be dismissed, since all of the countries[3] have experienced tropical cyclones, especially northeastern Honduras and Nicaragua, and Belize.

[1] Meteorological convention dictates that wind direction is the direction **from** which the wind is blowing i.e., easterly winds blow **from** the east (toward the west).

[2] See Subsubsection 3.2.3.

[3] Panama and Costa Rica, minimally.

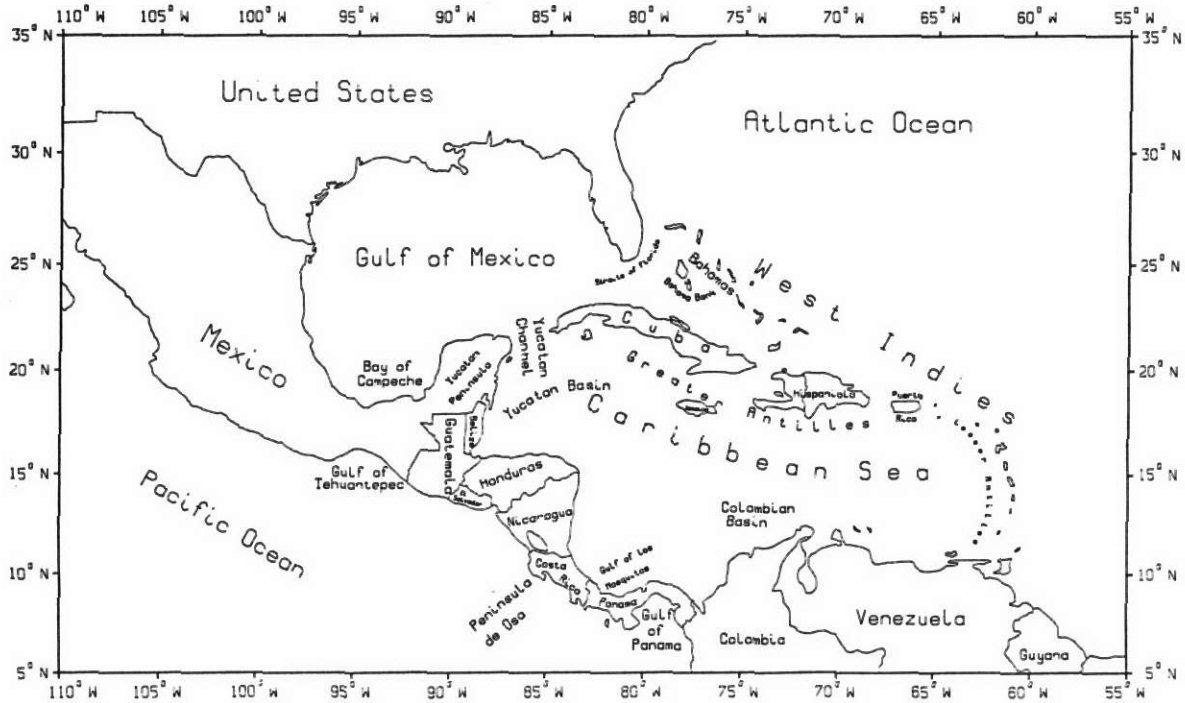

Figure 1.1: Central America and Surrounding Region (NOCD, Asheville, 1985)

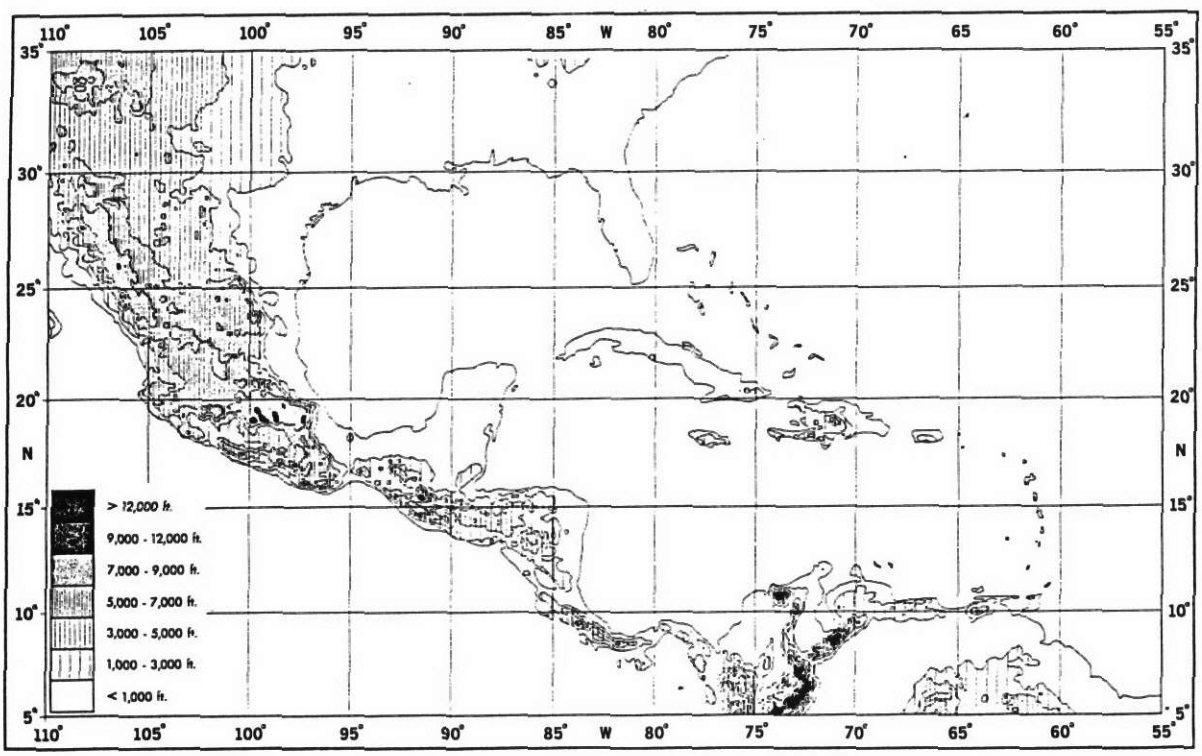

Figure 1.2: Topography (NOCD, Asheville, 1985)

1.2 Regional Climatologies

1.2.1 Rainy Season and Dry Season Charts

While the appendices have extensive excerpts from more complete climatological references, the following sets of charts portray the features of the "rainy season" (August)[4] and the "dry season" (February).

Figures 1.3 and 1.4, from Sadler et al. (1987)[5], depict the resultant surface wind direction and speed, for August and February, respectively. The migration of surface convergence over the North Pacific Ocean, from near 10°N in August southward to near 5°N in February, is obvious.

Figures 1.5 and 1.6, from Sadler and Wann (1984), depict the mean 200 mb (upper tropospheric) flow[6] for August and February, respectively. In August, the mean position of the Tropical Upper Tropospheric Trough (TUTT) extends eastward from just north of Belize separating the subtropical ridge (in the northern Gulf of Mexico) and the subequatorial ridge (extending from southern Guatemala through Nicaragua, eastward). The greater geopotential heights found in the subequatorial ridge correlate well with the enhanced convection associated with the more northerly August position of surface convergence (called, by some, the Intertropical Convergence Zone (ITCZ)). However, the mean 200 mb flow in February is southwesterly, increasing from an average 10 kt south of Panama to 40 kt just north of Belize.

Figures 1.7 and 1.8 from Sadler et al. (1987) depict averaged sea-level pressure for August and February, despite the preference of streamline/isotach analysis over pressure (or contour) analysis in the tropics (see Appendix A). It is immediately obvious that the lowest average sea-level pressure (for this large (synoptic) scale) is found over Panama and Costa Rica in both the rainy and dry seasons.

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[4]These representative months have been rather arbitrarily selected. See Subsection 1.2.2 for further explanation. While Portig (1976) divides Central America into 14 rainfall regimes, USAFETAC (1985) supports the selection of these months, but includes "transitional" months between the rainy and dry seasons for Nicaragua, as well as a secondary rainfall maximum for Panama in October.

[5]Only the last 80 years, 1900 - 1979, have been used from the Comprehensive Ocean-Atmosphere Data Set (COADS). COADS is a continuing cooperative effort to compile global ship observations (initially for the period 1850 - 1979) between the National Oceanic and Atmospheric Administration (NOAA)—its Environmental Research Laboratories, National Climatic Data Center (NCDC) and Cooperative Institute for Research in Environmental Sciences (CIRES)—and the National Science Foundation's National Center for Atmospheric Research (NCAR). Details of how the ship observations were collected, evaluated and compiled are contained in Woodruff et al. (1987).

[6]The period of record is 1960 - 1973, consisting of 175,000 PIREP and RAWIN observations per month.

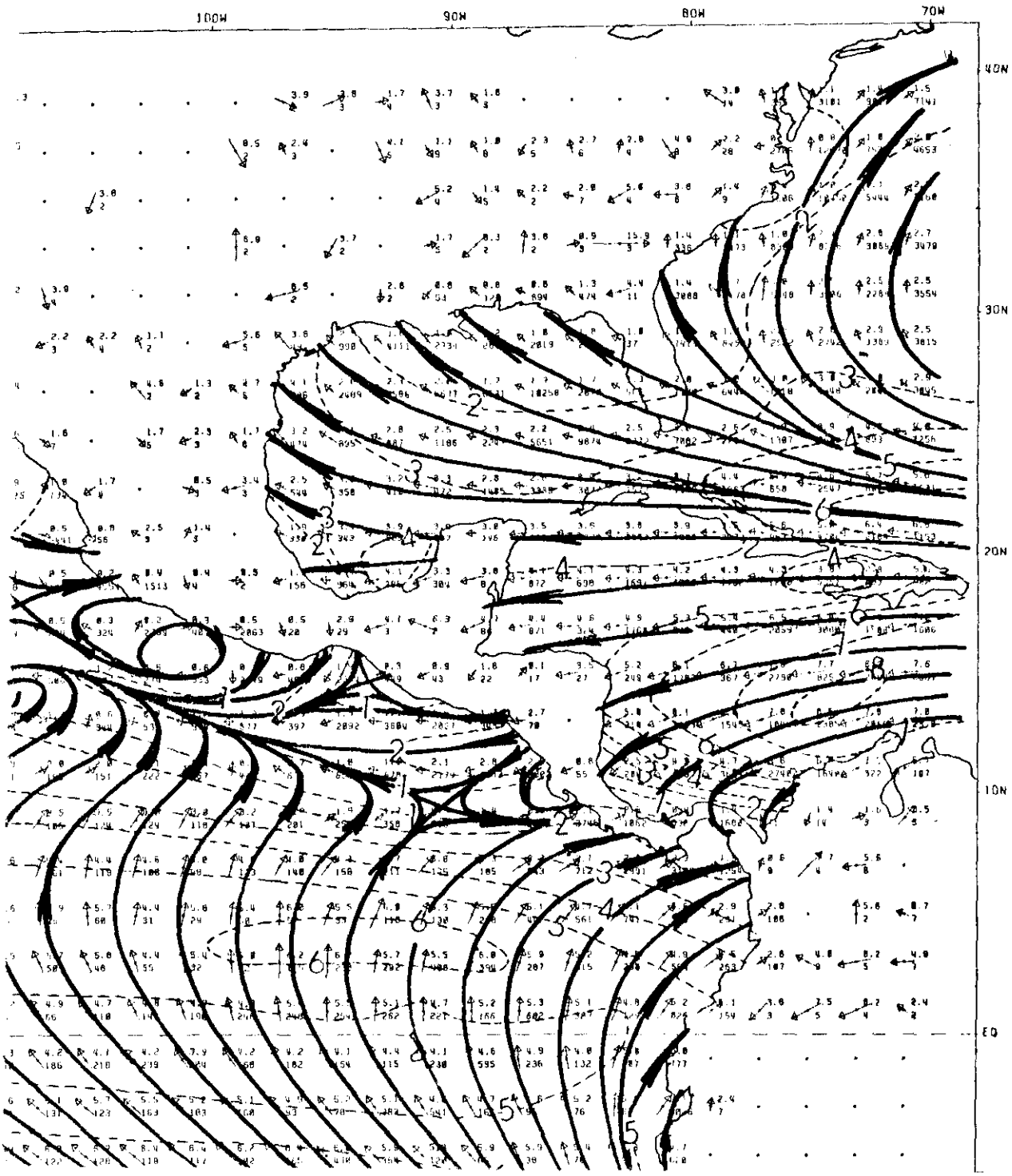

Figure 1.3: Surface Wind Direction / Speed (2° by 2°) Grid, August (Sadler et al., 1987) The resultant direction is depicted by streamlines and the resultant speed in m/sec by dashed lines. (Data plots contain (1) upper number: monthly average wind speed and (2) lower number: number of observations within each 2° square—arrow shaft length is proportional to wind speed.)

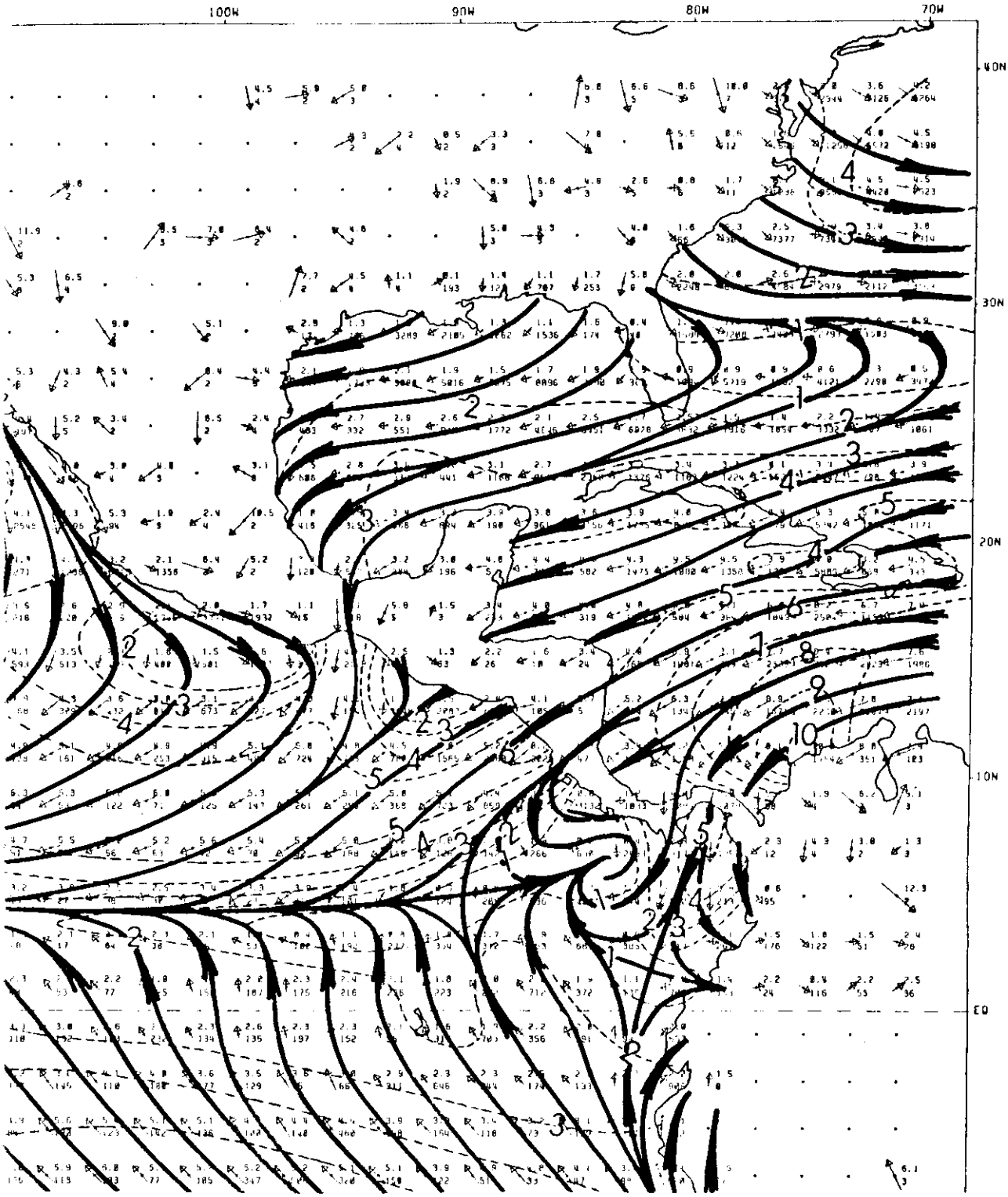

Figure 1.4: Surface Wind Direction / Speed (2° by 2°) Grid, February (Sadler et al., 1987) The resultant direction is depicted by streamlines and the resultant speed in m/sec by dashed lines. (Data plots contain (1) upper number: monthly average wind speed and (2) lower number: number of observations within each 2° square—arrow shaft length is proportional to wind speed.)

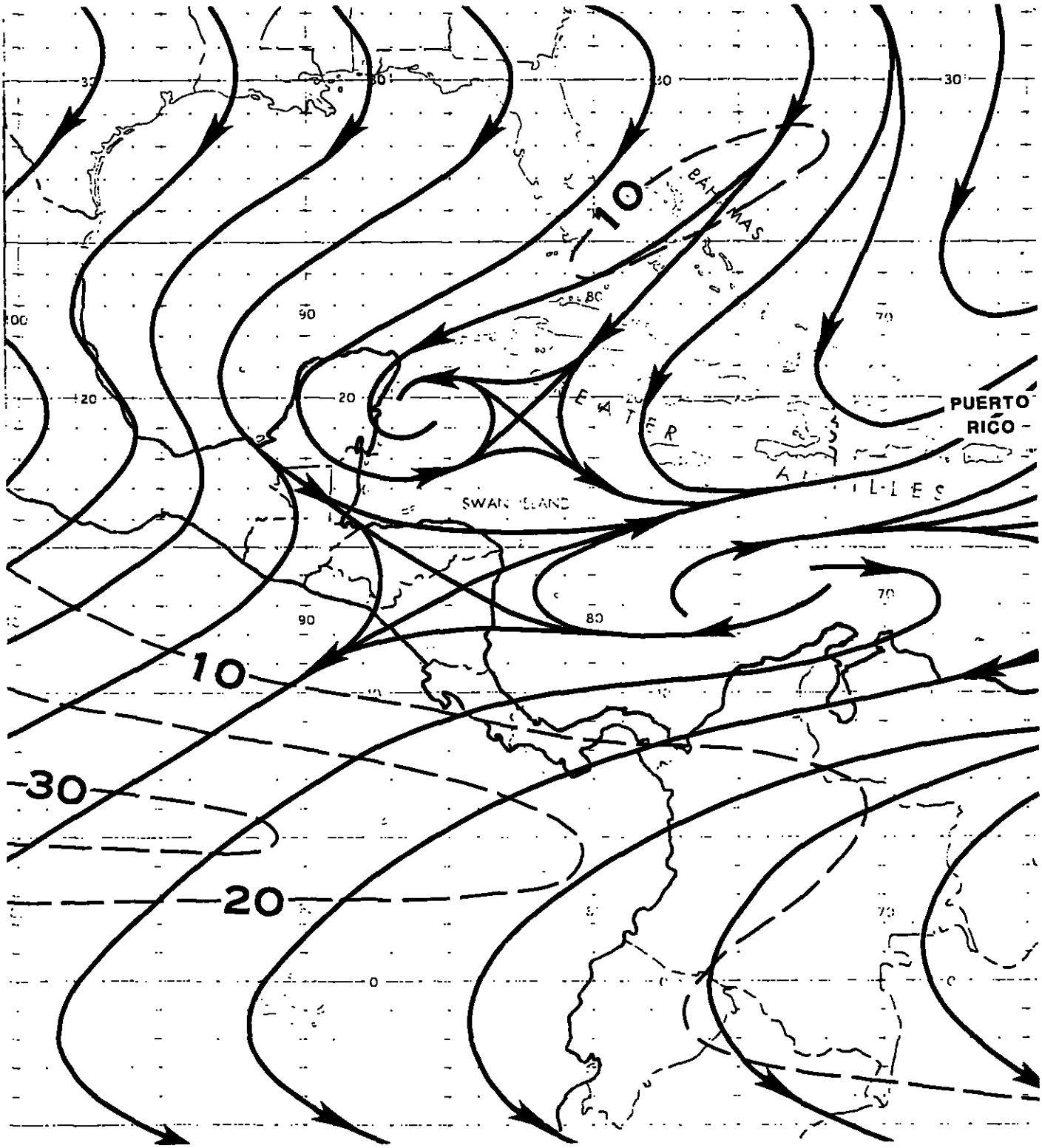

Figure 1.5: Mean 200 mb Flow, August (Sadler and Wann, 1984)
Streamlines (solid, with arrows indicating direction of flow) and isotachs (dashed) in knots

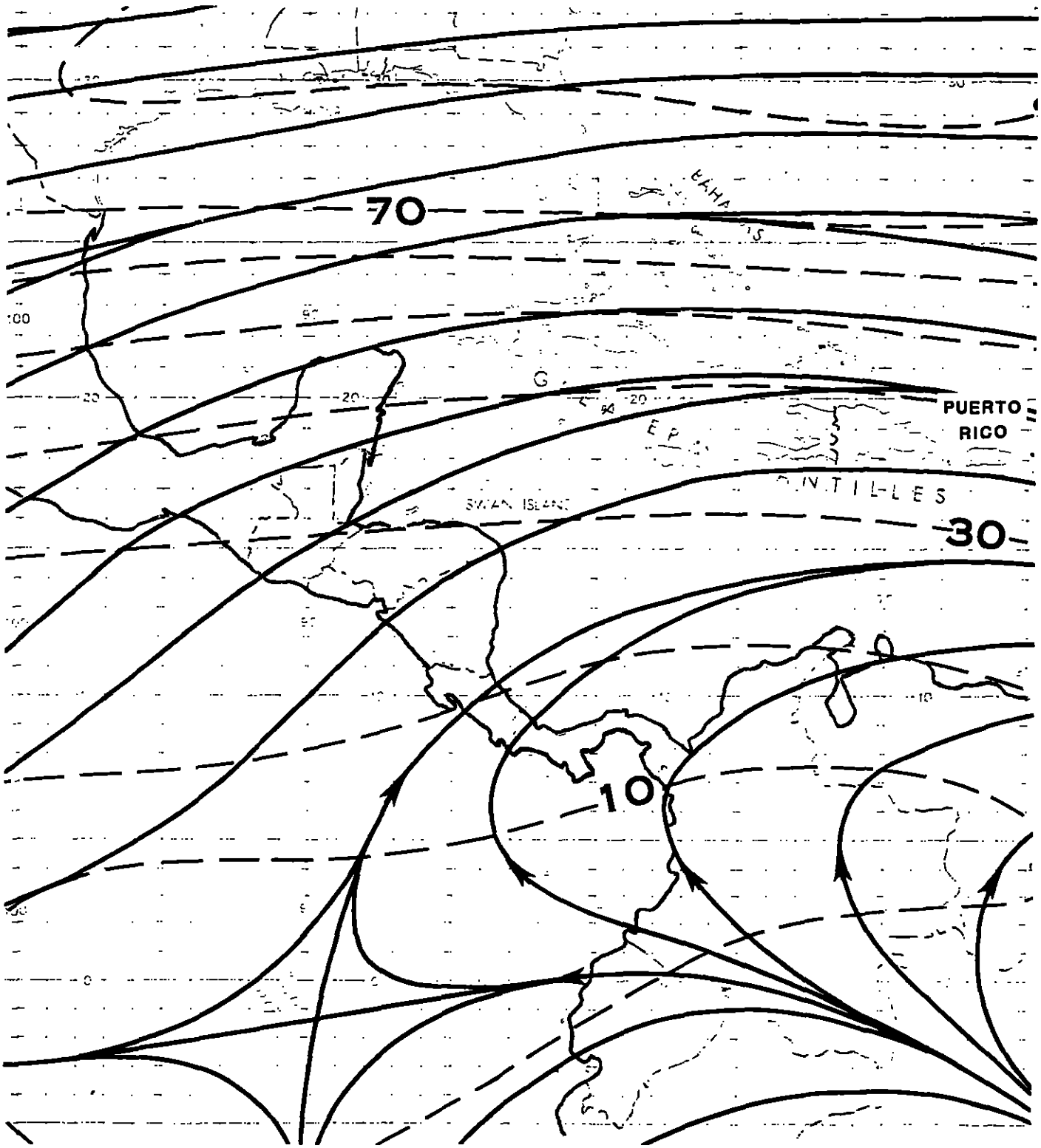

Figure 1.6: Mean 200 mb Flow, February (Sadler and Wann, 1984)
Streamlines (solid, with arrows indicating direction of flow) and isotachs (dashed) in knots

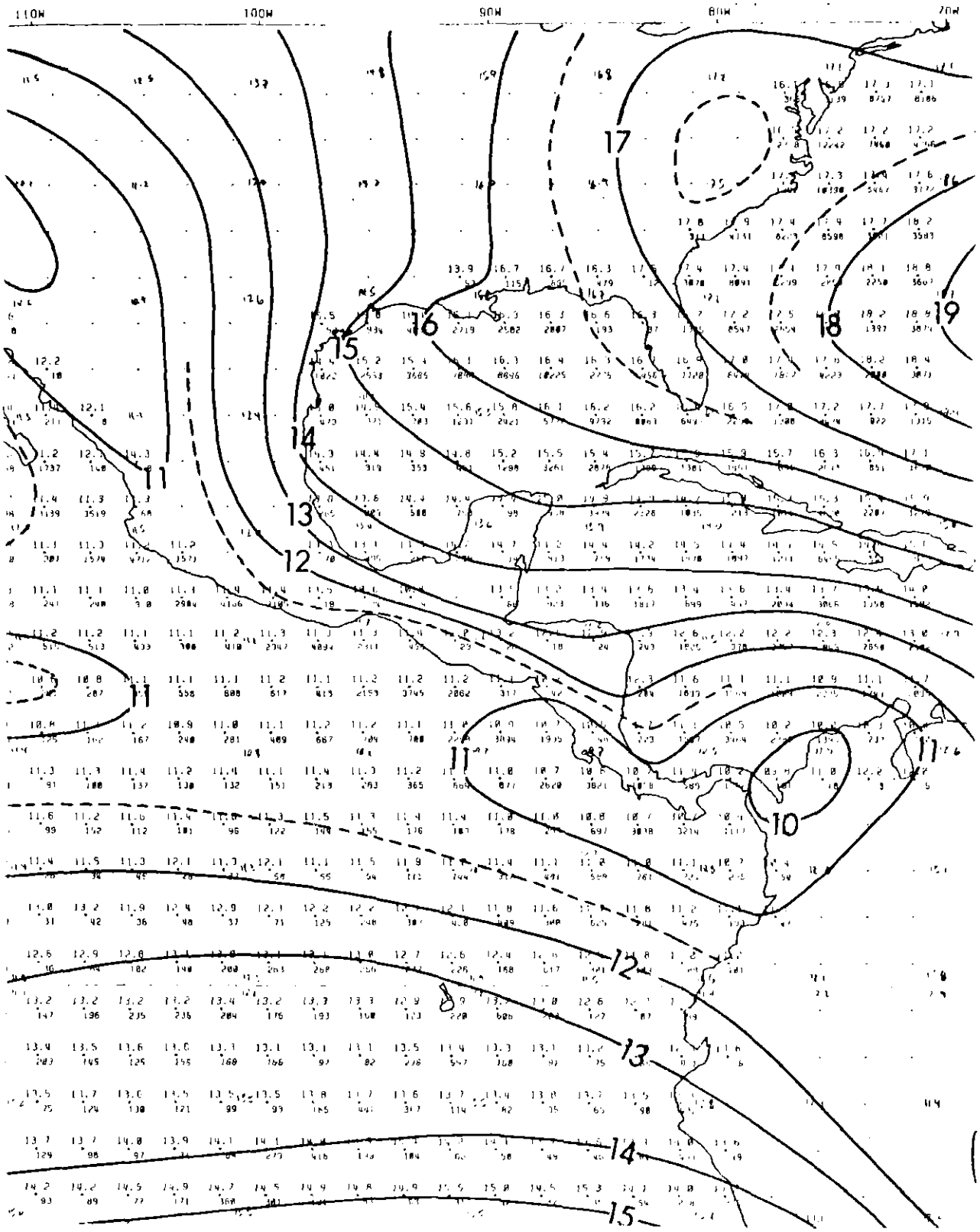

Figure 1.7: Mean sea-level Pressure, August (Sadler et al., 1987)
The isobars are labeled in millibars (or hectopascals (hPa)) with the leading 10 omitted. Selected one-half millibar intervals are shown as dashed lines.

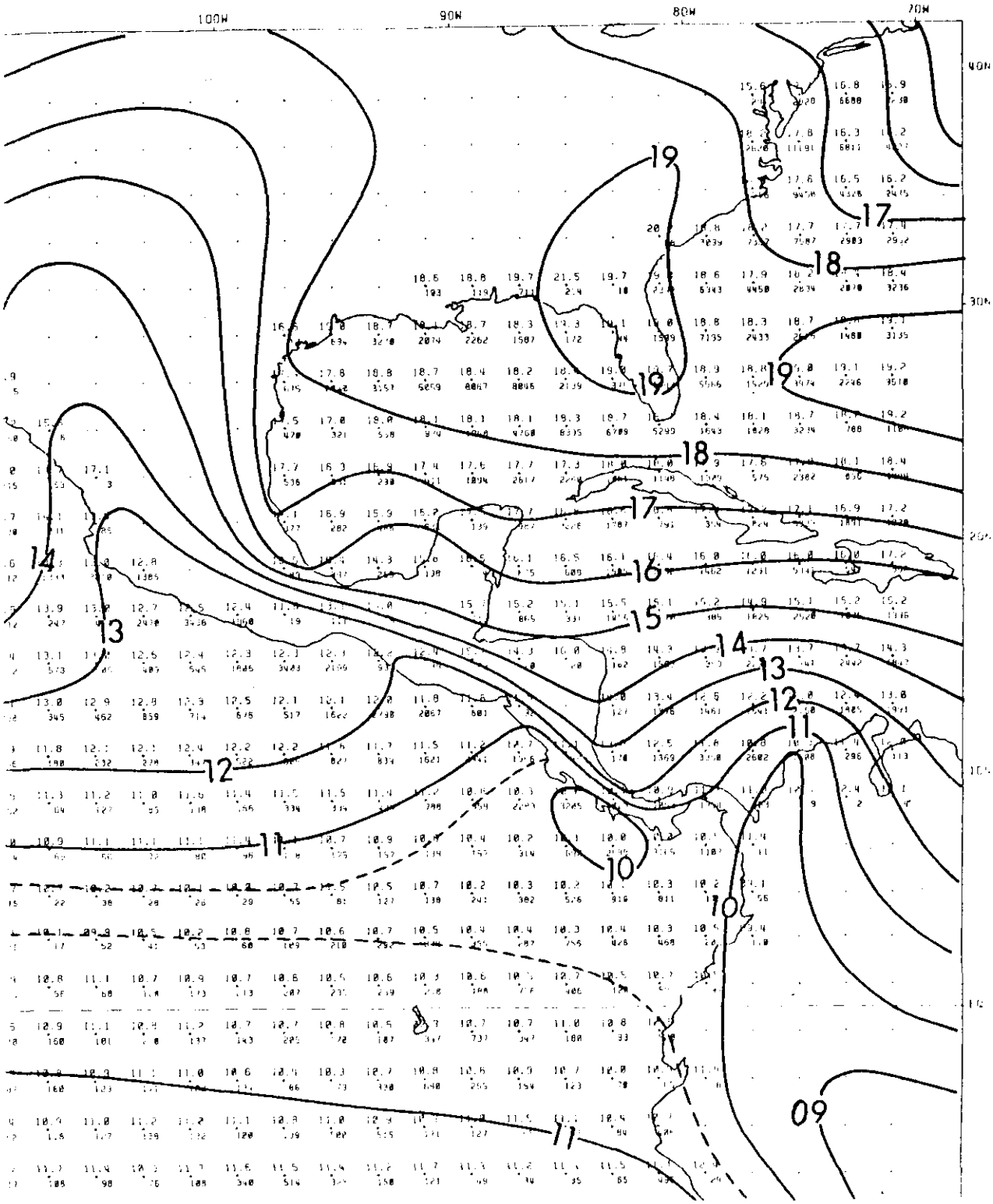

Figure 1.8: Mean sea-level Pressure, February (Sadler et al., 1987)
The isobars are labeled in millibars (or hectopascals (hPa)) with the leading 10 omitted. Selected one-half millibar intervals are shown as dashed lines.

Figures 1.9 and 1.10 (NOCD, Asheville, 1985) depict the mean scalar wind speed for August and February. Note that the sea-level pressure figures, (1.7 and 1.8), and these figures of mean surface wind speed are from *different* references. The strength of the wind is greatest off the Caribbean coast of Columbia—a region known by oceanographers as the "Columbian Basin". Recalling, again, that these are *average* winds, note the strength of the trade winds in February, reaching into the North Pacific Ocean after crossing the relatively flat southern Nicaragua, as contrasted to the very light winds southwest of the mountainous Costa Rica.

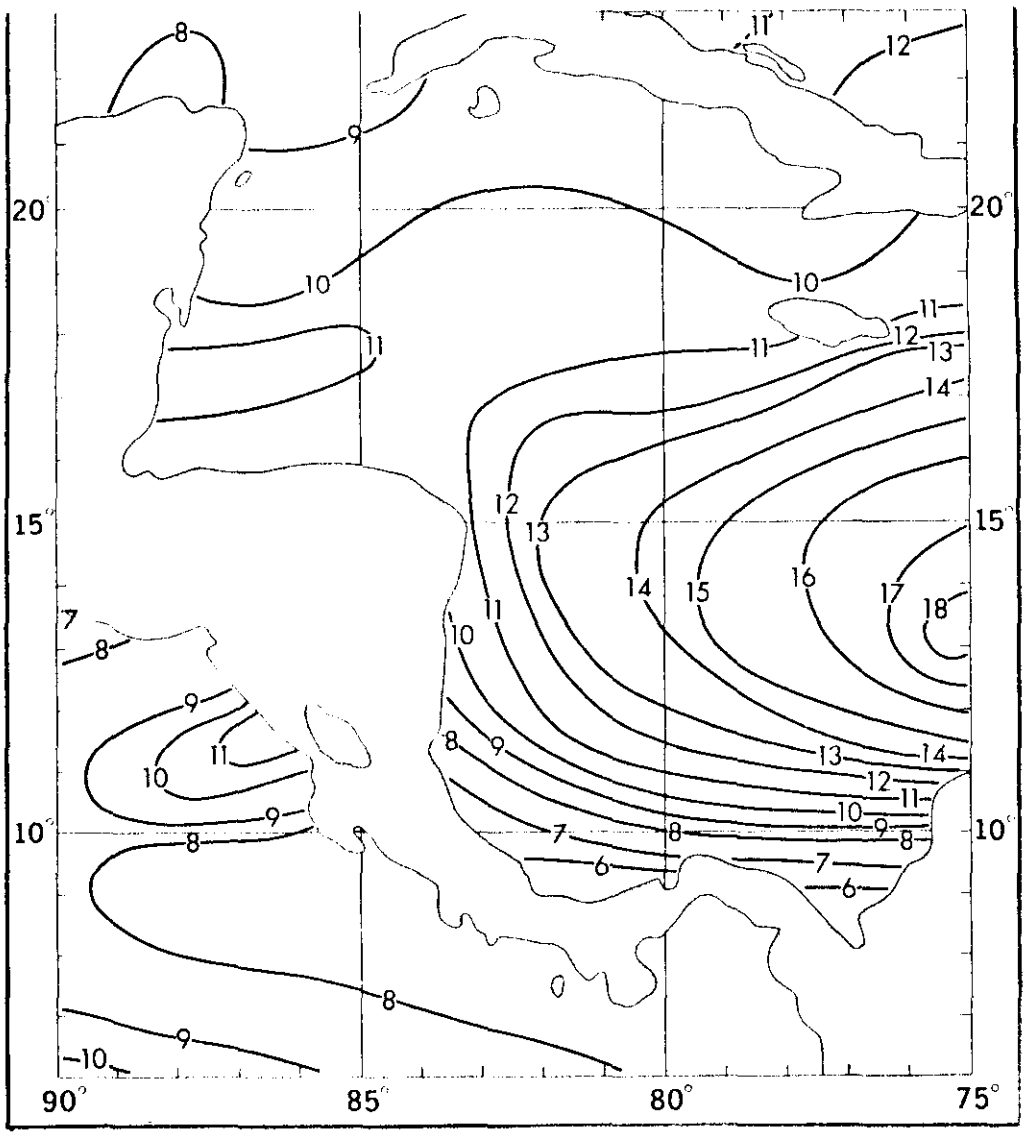

Figure 1.9: Mean Scalar Surface Wind Speed (kt), August (NOCD, Asheville, 1985)

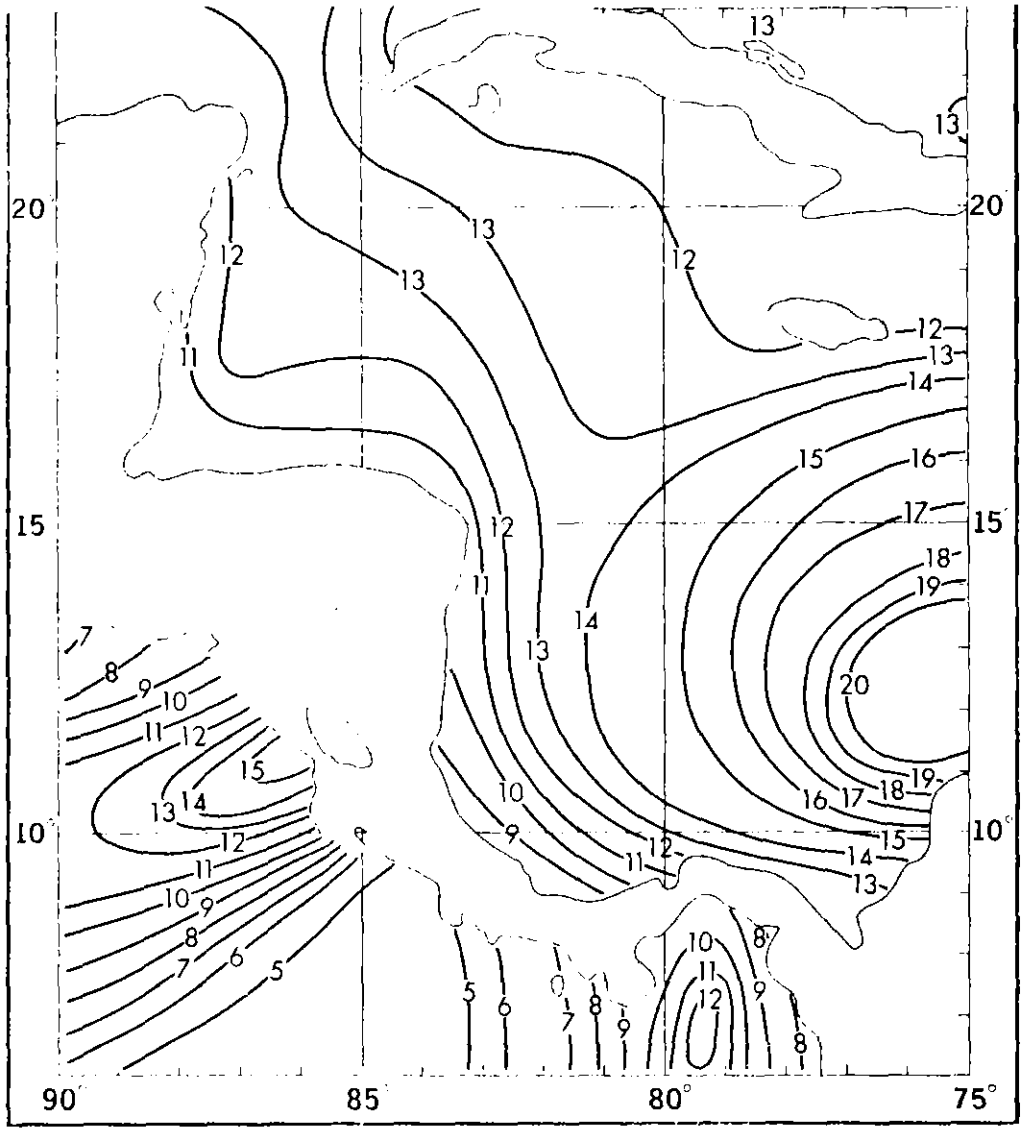

Figure 1.10: Mean Scalar Surface Wind Speed (kt), February (NOCD, Asheville, 1985)

Figures 1.11 and 1.12 (NOCD, Asheville, 1985) depict isopleths showing the percentage frequencies of wave heights $\geq$ 3 feet (solid lines) and $\geq$ 8 feet (dashed lines) for August and February. In agreement with the wind speed depicted in Figs. 1.9 and 1.10, large wave heights are more often found over the Columbian Basin, regardless of season. While wave heights surrounding Central America are generally high more often on the Caribbean side (the windward side) in February, note that wave heights on the North Pacific Ocean side are smaller in the lee of mountainous Costa Rica, but much larger west of Nicaragua.

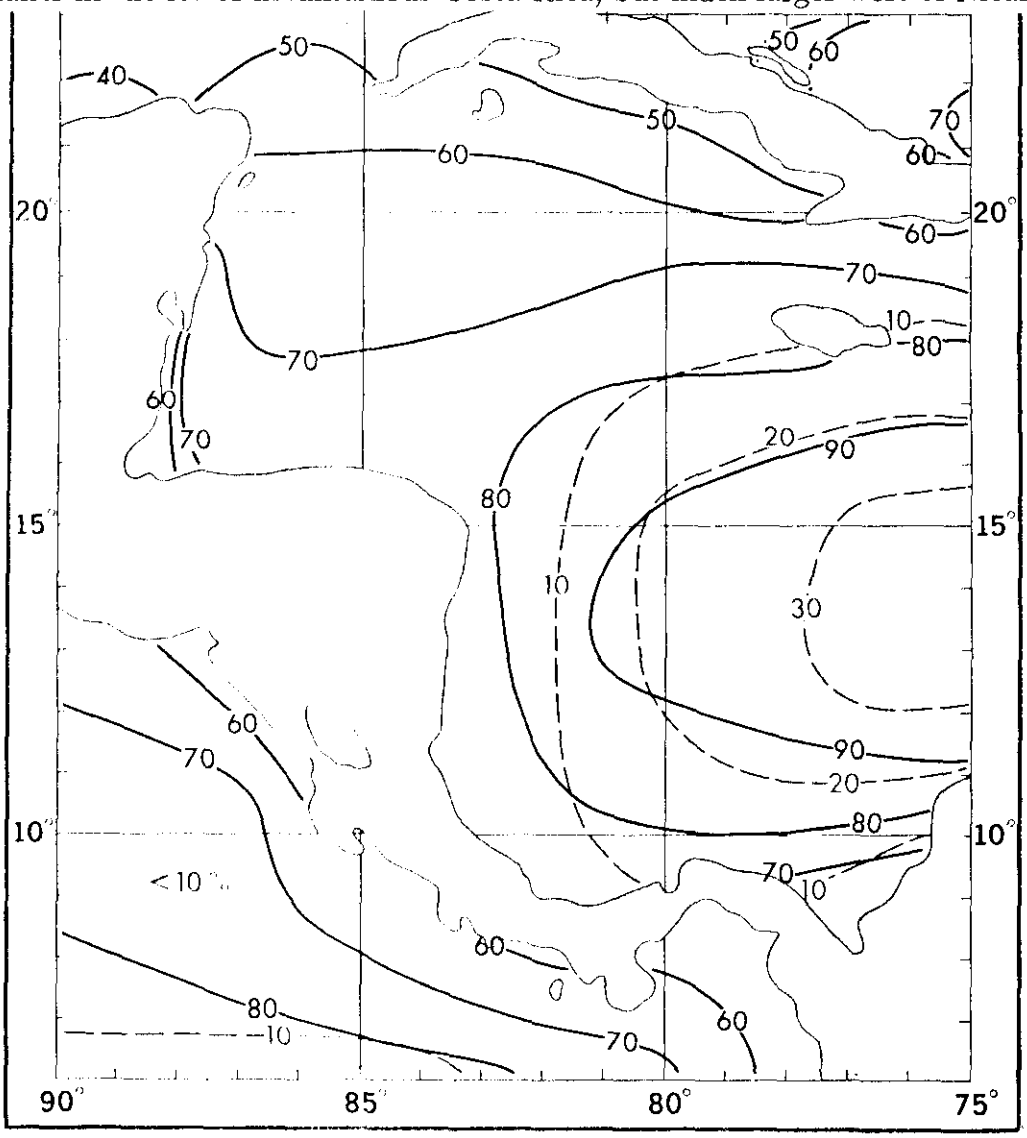

Figure 1.11: Wave-height Isopleths (Percent Frequency) August (NOCD, Asheville, 1985)
Solid line - Wave height $\geq$3 feet; Dashed line - Wave height $\geq$8 feet.
The wave height is the higher of sea or swell for observations containing both wave trains. Sea is defined as waves generated by local winds.

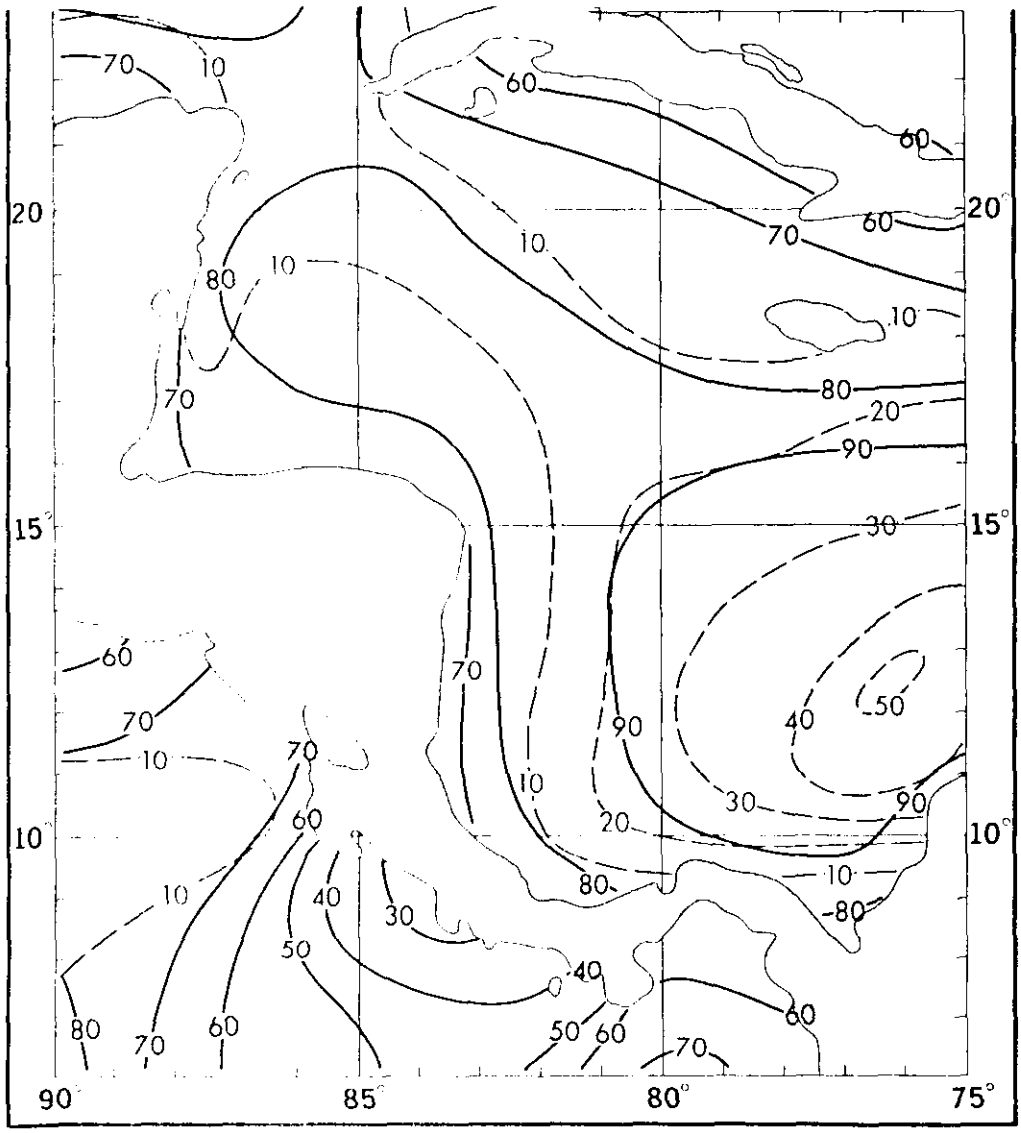

Figure 1.12: Wave-height Isopleths (Percent Frequency) February (NOCD, Asheville, 1985)
Solid line - Wave height $\geq$3 feet; Dashed line - Wave height $\geq$8 feet.
The wave height is the higher of sea or swell for observations containing both wave trains. Sea is defined as waves generated by local winds.

Figures 1.13 and 1.14 (Sadler and Wann, 1984) depict the mean monthly cloudiness over Central America and the adjacent waters during the period 1965–1973. The analysis was derived from operational nephanalyses[7] with isopleths labeled in "octas"[8] (eighths) of total cloud cover. There is no satisfactory "ground truth" monthly average cloud analyses to which this analysis can be compared. However, the patterns of cloudiness and the positions of the maximum and minimum areas of cloudiness are essentially identical to other *satellite* derived analyses—although there is an average difference of about 1 octa between different satellite analyses.

It is readily apparent that average monthly cloudiness over much of Central America decreases from ~5/8 in August (the rainy season, Fig. 1.13) to ~3/8 in February (the dry season, Fig. 1.14).

Figures 1.15 and 1.16 (Sadler *et al.*, 1987), depict the mean sea-surface temperature (SST) during the months of August and February. During August, monthly SST in the waters surrounding Central America is generally between 28°C and 29°C. Again, note that the higher winds blowing from land toward the North Pacific Ocean, west of Nicaragua in February, lead to mixing of the upper layer of the ocean and to cooler temperatures (~26°C) than found in the North Pacific Ocean west of Costa Rica(~28°C) where winds are weaker.

[7]Nephanalysis is a mapped analysis of the cloud distribution or "the analysis of a **synoptic chart** in terms of the types and amount of clouds and precipitation" (Huschke, 1959).

[8]Sadler emphasized the spelling of these labels so as to differentiate them from the fraction of cloud cover in "oktas" used by the World Meteorological Organization for *ground* based estimates.

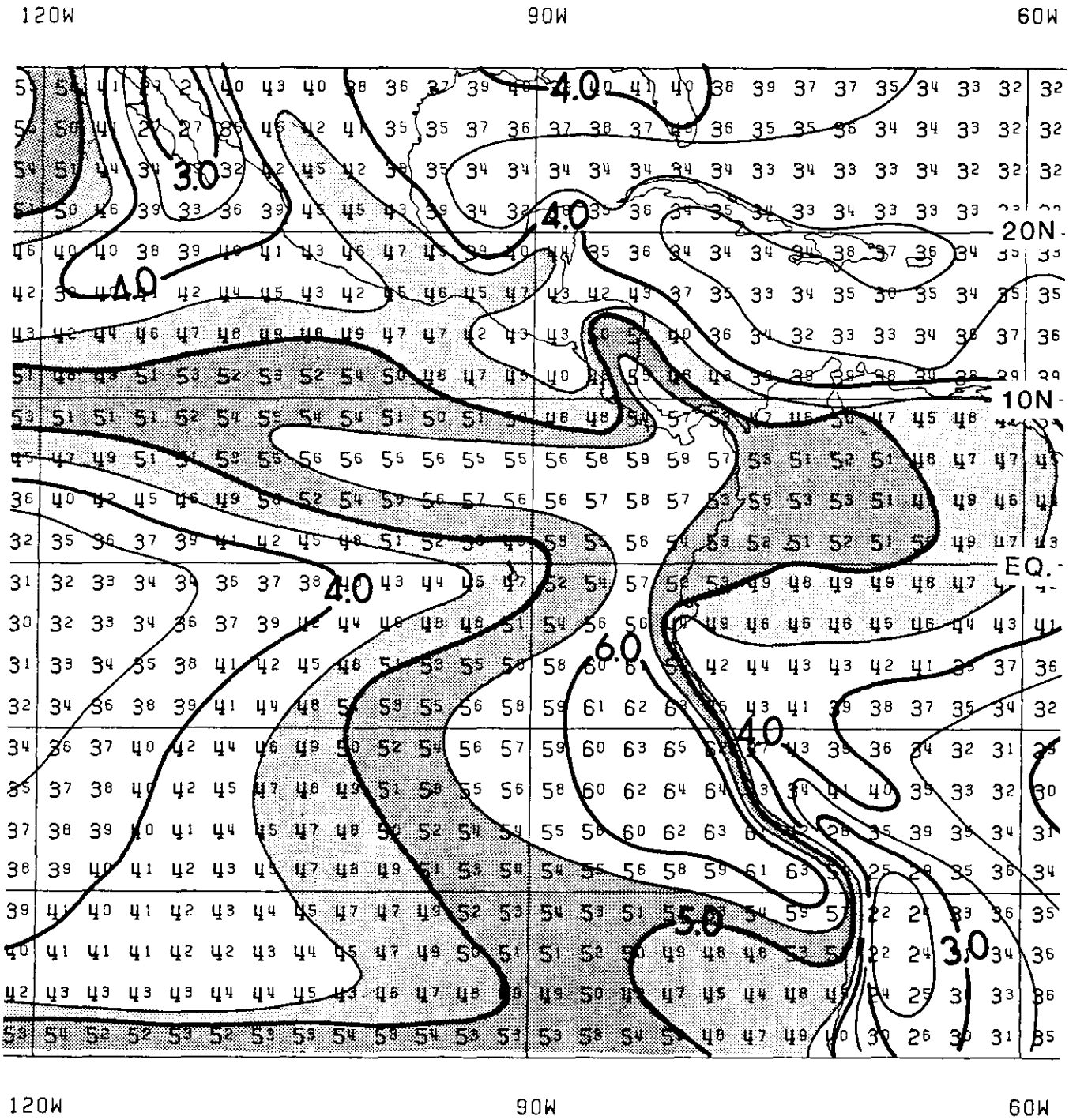

Figure 1.13: Mean Monthly Cloudiness in Octas, August (Sadler and Wann, 1984) The average cloud cover is plotted for each 2.5° latitude-longitude square.

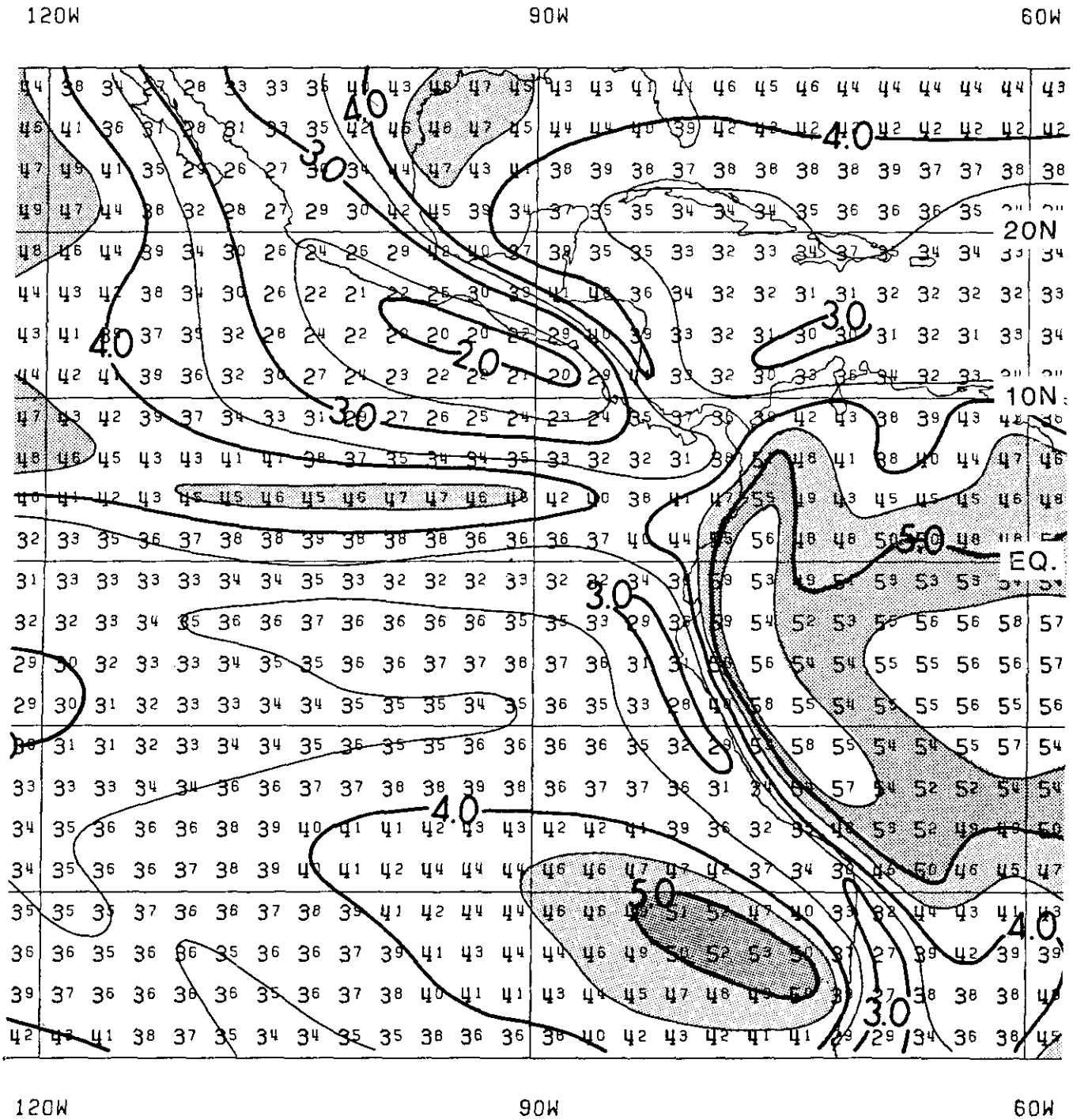

Figure 1.14: Mean Monthly Cloudiness in Octas, February (Sadler and Wann, 1984) The average cloud cover is plotted for each 2.5° latitude-longitude square.

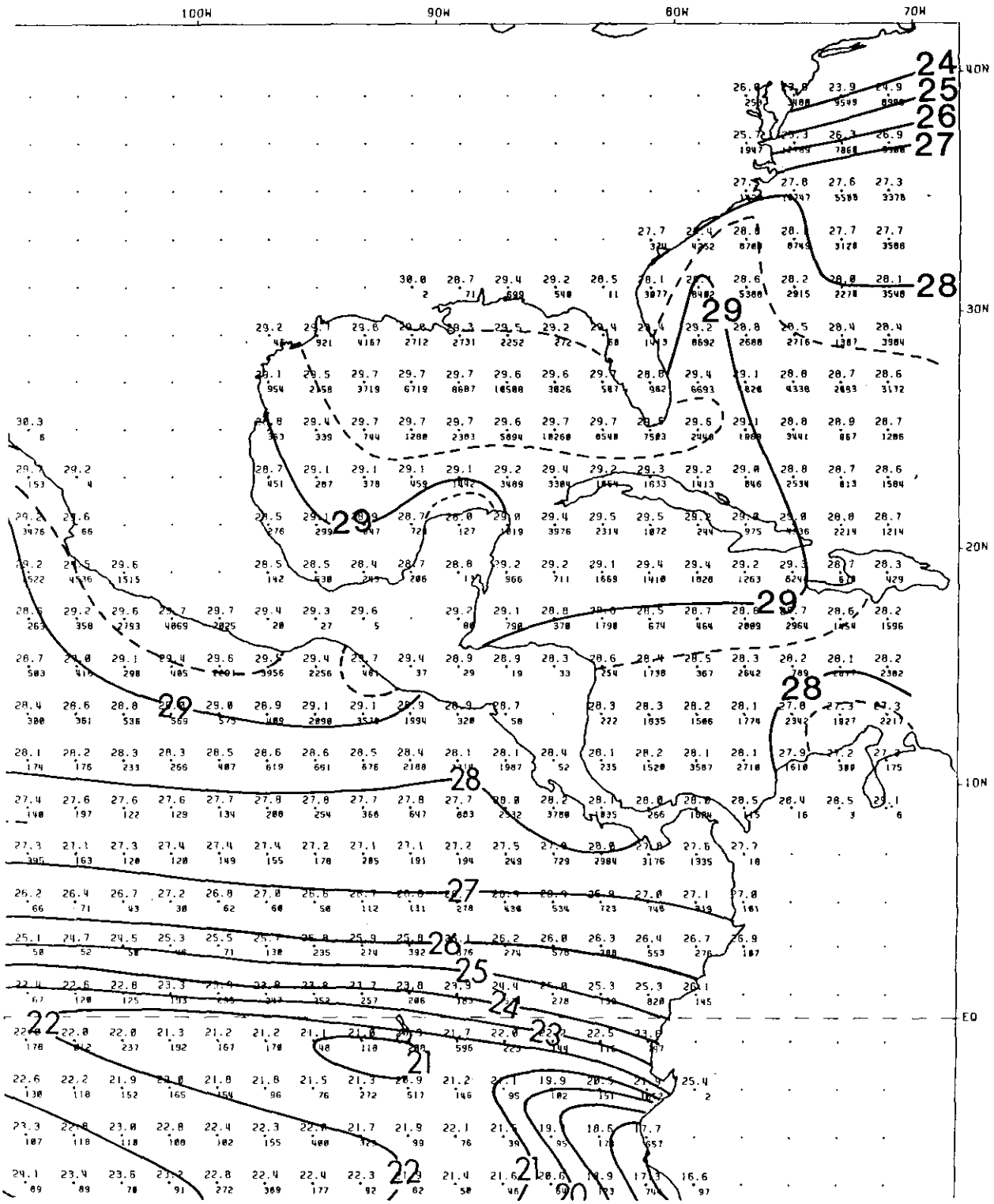

Figure 1.15: Mean Sea-Surface Temperature, August (Sadler et al., 1987)
The isotherms are labeled in degrees Celsius. Where needed, one-half degree intervals are shown as dashed lines.

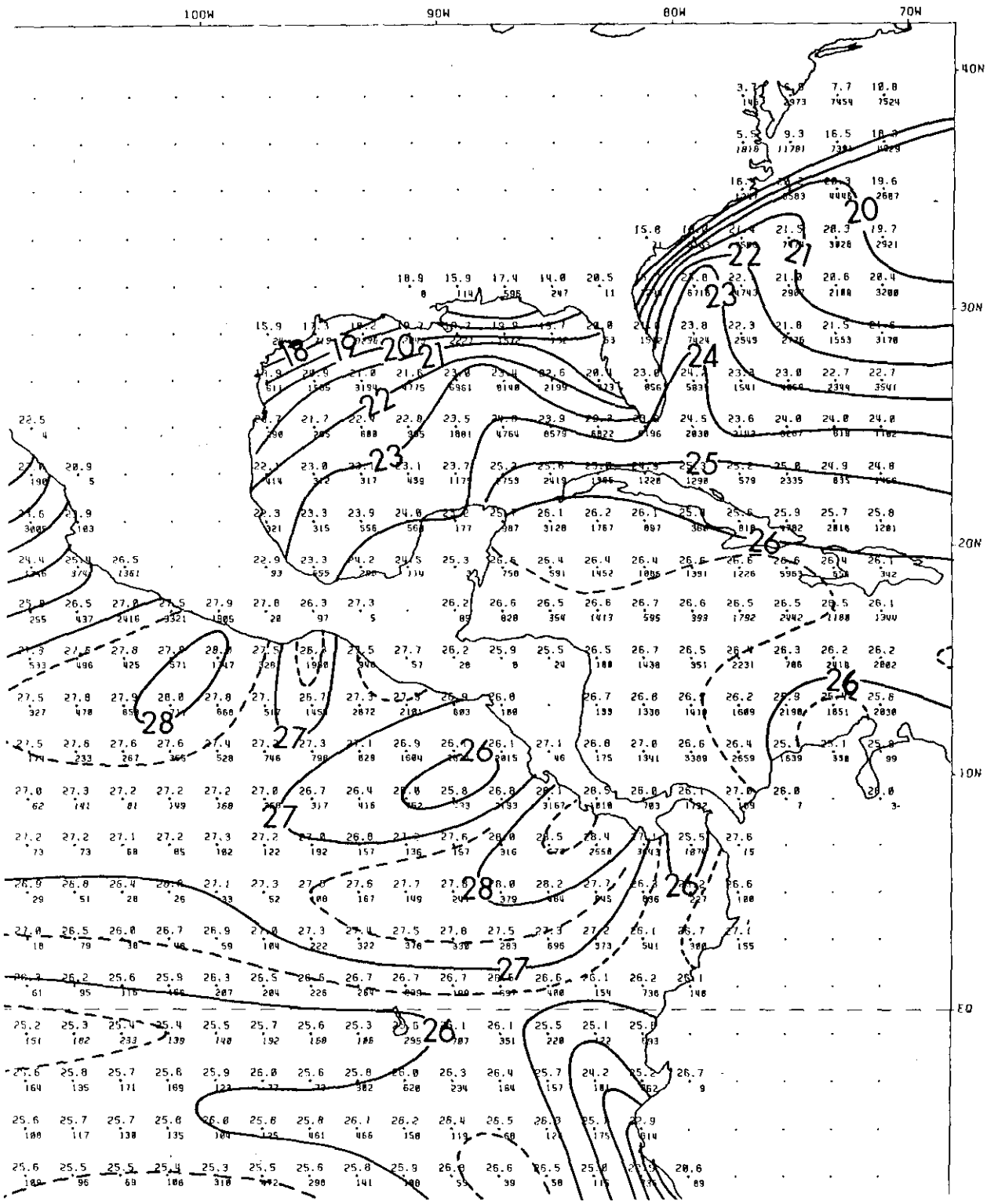

Figure 1.16: Mean Sea-Surface Temperature, February (Sadler et al., 1987)
The isotherms are labeled in degrees Celsius. Where needed, one-half degree intervals are shown as dashed lines.

Finally, to assist mid-latitude meteorologists to adapt to the tropical setting of Central America, a *mean* sounding will be presented. While the International Civil Aviation Organization (ICAO) sounding[9] with sea-level temperature of 15°C, as well as 500 mb height of 5574 m and temperature of -21.2°C, is so commonly used in extratropical applications, the mean atmosphere of Central America is obviously much warmer (and much more moist) with typically higher heights for constant pressure surfaces.

Jordan (1958) prepared a mean sounding from ten years of data from three stations: Miami, Florida; San Juan, Puerto Rico; and Swan Island[10]. The *annual* sounding is considered less useful and will not be presented since it provides a rather nonexistent sounding between the rainy and dry seasons.

Table 1.1 depicts the mean pressure, height, temperature and specific humidity of the four months[11], July through October, typical of the rainy season. To avoid the effects of daytime radiation, Jordan averaged only night time soundings—0300 GMT, as obtained operationally during the 1946–1955 period. Figure 1.17 presents a plot of this mean tropical sounding for the four summer months. Unlike the so familiar ICAO (or "U. S. Standard Atmosphere") **extra**tropical mean sounding, there is a dewpoint temperature sounding, available from the specific humidity data provided in Table 1.1.

[9]Identical with the U. S. Standard Atmosphere up to a height of 32 km.

[10]Swan Island is located at 17°N, 84°W in the western Caribbean Sea, ~100 miles north of eastern Honduras (see Fig. 1.21).

[11]Defined by Jordan to be the "hurricane season".

Table 1.1: Mean Tropical Atmosphere (West Indies) during Rainy Season (Jordan, 1958)

Pressure (mb)	Height (m)	Temperature (°C)	Specific Humidity (g/kg)
80	17883	-69.8	
100	16568	-73.5	
125	15260	-72.2	
150	14177	-67.6	
175	13236	-61.5	
200	12396	-55.2	
250	10935	-43.3	
300	9682	-33.2	
350	8581	-24.8	
400	7595	-17.7	
450	6703	-11.9	1.4
500	5888	-6.9	2.1
550	5138	-2.5	3.2
600	4442	1.4	3.6
650	3792	5.1	4.6
700	3182	8.6	5.8
750	2609	11.8	7.1
800	2063	14.6	8.4
850	1547	17.3	11.0
900	1054	19.8	13.0
950	583	23.0	15.3
1000	132	26.0	17.6

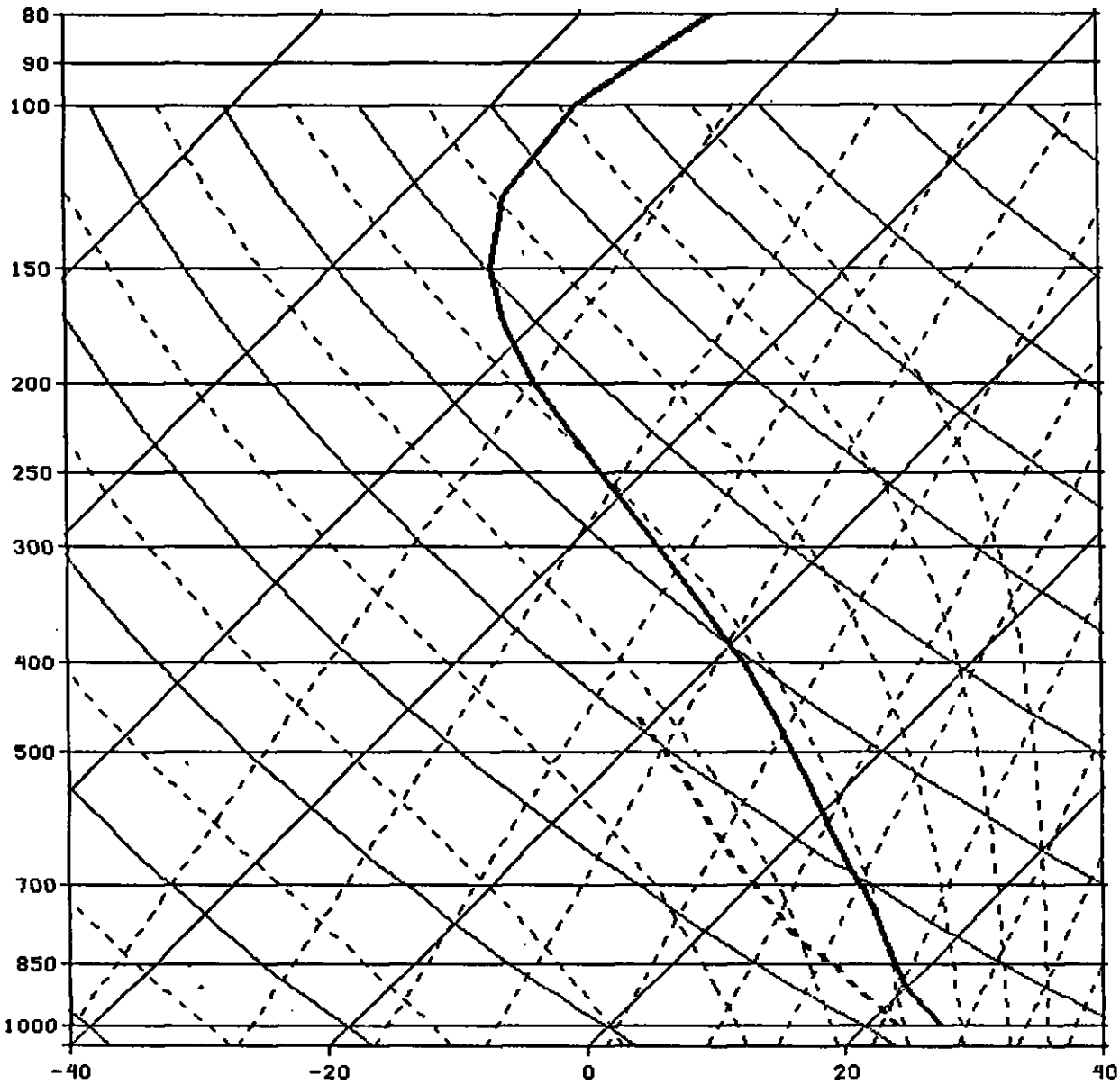

Figure 1.17: Mean Tropical Atmosphere (West Indies) during Rainy Season (Jordan, 1958) The temperature (heavy solid line) and dewpoint temperature (heavy dashed line) are plotted on a "Skew T, Log P" thermodynamic diagram, with isobars (thin solid horizontal lines), "skewed" isotherms (thin solid lines) sloping from lower left to upper right, dry adiabats (thin solid lines) sloping from lower right to upper left, pseudoadiabats (thin dashed lines) sloping from lower right to upper left, and mixing ratio lines (thin dashed lines) sloping from lower left to upper right.

1.2.2 General Climatology (Portig, 1976)

The following outline contains summary statements gleaned from Portig (1976) concerning the various climatological elements for Central America. (The reader is cautioned that these summaries do not refer to the figures (from other sources) presented in the previous subsubsection.)

Wind

Because wind is among the climatological elements most affected by local influences in the near Equatorial portion of Central America, one cannot use the geostrophic or gradient approximation for the wind. Using earlier data based primarily on ship observations (yet, not so complete as COADS), Portig (1976) states that mean streamlines from September (rainy season) and December (dry season) have the greatest month-to-month mutual deviations (see Fig. 1.18 below)[12]. While the more northerly direction of the December winds is obvious, he notes that "in no month is there any (average) *southerly* component of the wind over the open Caribbean Sea".

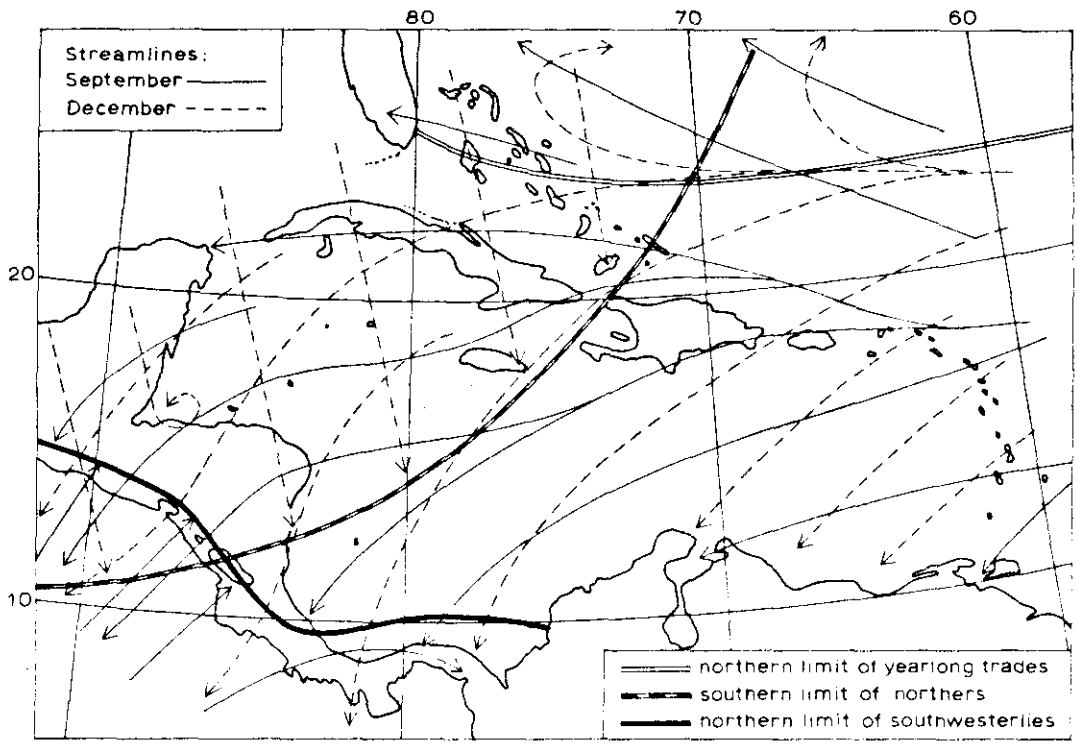

Figure 1.18: Mean Streamlines. Over the North Pacific coast of Central America two wind regimes alternate in September (Portig, 1976)

[12]The dashed lines from the north-northwest over the western Caribbean Sea indicate the presence of "northers", **intermittently** present with the north-northeasterly tradewinds during December. Northers are defined as "...strong, cold winds...associated with the southward movement of a cold anticyclone." (Huschke, 1959). However, other sources document northers reaching **Panama**.

Although hurricanes do occur in the region, they affect individual stations so seldom that their presence is not evident in wind statistics compiled over many years.

Not only do *inland* stations have a high percentage of calms, but there are periods (of hours) during which the wind speed is zero. Balloon records have revealed layers, several thousand meters thick, having no horizontal motion.

Stations have distinct diurnal variations, with the expected higher wind speeds in the afternoon and early evening. Stations with extensive land mass behind them, such as along the North Pacific coast, experience "sea breeze fronts". However, local orographic effects, "northers" and trade winds have their particular months (as well as time of day) of dominance.

Barometric Pressure

Relative maxima in mean pressure are found in December (or January) and in July. More importantly, the atmospheric pressure displays the familiar **double** wave every day, with minima near 0400L[13] and 1600L, and maxima near 1000L and 2200L. At San Salvador, the magnitude of this twice daily pressure variation is as large as 4.2 mb in March.

Cloudiness

Central America is often under a canopy of cirrus (often tenuous), and even well-experienced observers often have difficulty in locating the edges of thin cirrus. However, tropical clouds show a high correlation with geographic features, such that not only mountain ranges but also coastlines are often identified in satellite imagery. The largest annual range of cloudiness over ocean areas (i.e., clearer in February/March, cloudier in September) is observed in the North Pacific Ocean, off the coast of Central America. Maximum cloud cover is also found along the east coast of Central America, from Belize to Panama.

Sunshine

Mean monthly sunshine, in percentage of the possible, shows a tendency for stations to have their sunshine extremes out of phase and a month or so earlier than rainfall extremes. That is, minimum sunshine occurs one month before the rainfall maximum, and maximum sunshine occurs one month before the rainfall minimum.

Temperature

Since Central America is tropical and primarily maritime, temperature changes are small. Portig (1976) found that the *hourly* temperature variations from observations in a well ventilated shelter depend mostly on cloud cover.

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[13]L = Local Time

In most of Central America (except for the Caribbean coasts of Honduras and northern Nicaragua), the monsoon temperature variation dominates with the highest temperatures just before the onset of the summer rains. On land, the average temperature of the *warmest* month (at sea level) is less than 29°C, except at some island locations on the Pacific side of Central America where the mean April temperature rises to 31°C (e.g., in Amapala, a Honduran island in the Gulf of Fonseca[14]). Conversely, at sea level the average temperature of the *coldest* month is 19°C. The annual temperature range for most of Honduras is more than 4°C, dropping to less than 4°C at the coast, and to about 1.5°C at the Panama Canal. (The temperature range of stations at higher elevations is generally of the same magnitude as for nearby lowlands.)

Cold winter air invasions from North America affect the absolute temperature minima. While lowland temperatures almost never drop below 15°C southeast of a line running from Puerto Rico to Costa Rica, the lowland temperatures in Central America northwest of this line reach an absolute minima of approximately 7°C. Such low temperatures usually occur due to the combined effects of cold air intrusion and nocturnal cooling. The highest mountains of Guatemala and Costa Rica have experienced *below freezing* air temperatures.

The diurnal temperature range exceeds the annual temperature range, although the diurnal range is reduced by the nearness to sea. Also, the dry season has a larger daily temperature variation than the rainy season, in general.

Moisture

Most Central American climatological summaries do not include dewpoint temperatures; however, Appendix B contains average **monthly** relative humidity, vapor pressure and dewpoint temperature for selected stations. Although the strong influence of nearby oceans and warm temperatures dictates relatively high moisture for Central America, it is noted that moisture *can* drop to sufficiently low values where hygrometers become inaccurate.

Rainfall

Portig (1976) states that "the most important meteorological element in the tropics is the rainfall". Although Central America is practically always under the influence of maritime air masses, seasonal variation of precipitation are surprisingly high (see Fig. 1.19). While much of the variation can be attributed to orographic effects, significant differences in the timing of the rainfall seasons exists over short distances.

Areas of *lesser* rainfall (less than 100 cm (~40 in) include regions of elevated plains of central Guatemala, Honduras and northwestern Nicaragua, plus very small parts of the North Pacific coast west of the Gulf of Fonseca and southwest of Panama City.

[14]See Subsection 1.3 for geographical locations within respective countries.

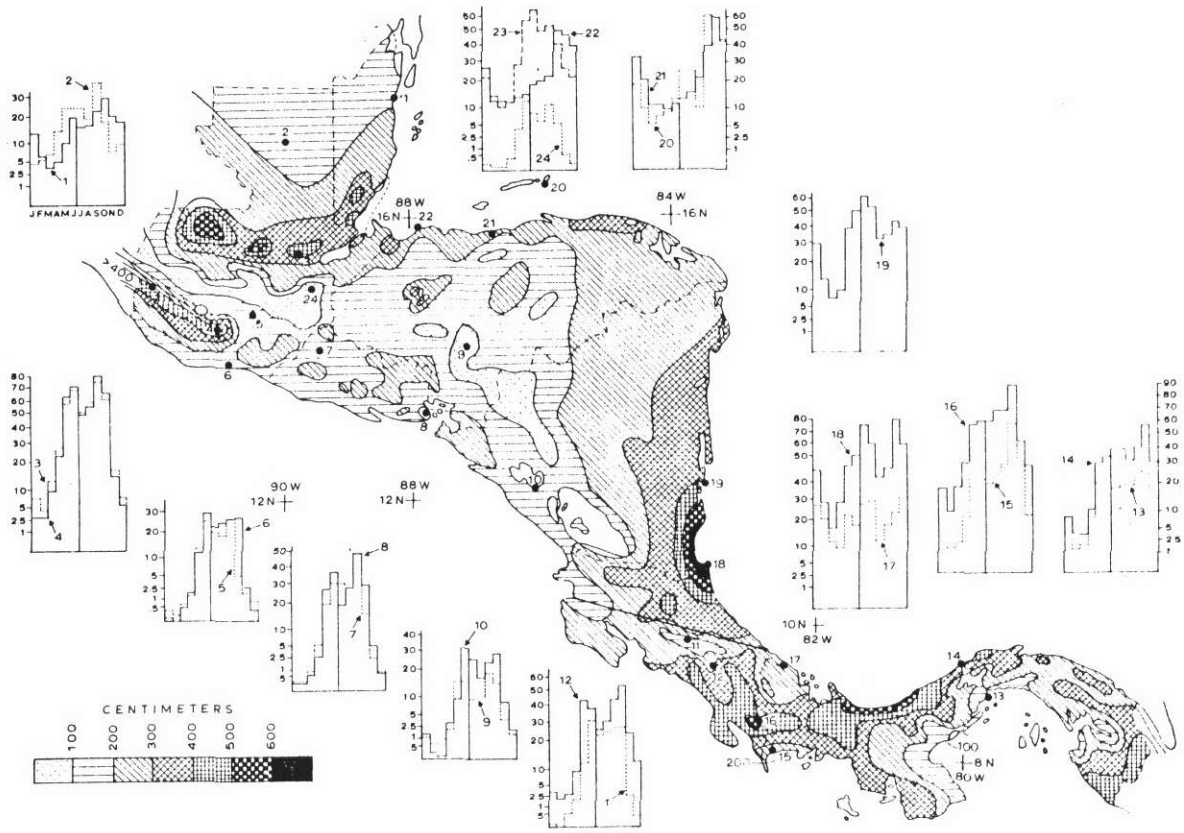

Figure 1.19: Mean annual rainfall (cm) in Central America (Portig, 1976). Numbers (1 through 24) locate the following stations: 1-Belize City, 2-Flores, 3-Santa Teresa, 4-San Andrés Osuna, 5-Guatemala City, 6-San José, G., 7-Texis Junction, 8-Cutuco, 9-Tegucigalpa, 10-Managua, 11-San José, C. R., 12-Villa Mills, 13-Panama City, 14-Colón, 15-Puerto Armuelles, 16-Caracol, 17-Guabito, 18-San Juan del Norte, 19-Bluefields, 20-Guanaja, 21-La Ceiba, 22-Puerto Cortés, 23-Sepacuite, 24-Zacapa.

In contrast, areas of excessive rainfall are found in the mountains of Guatemala and the mountains connecting Costa Rica and Panama. The tops of lesser mountains and the slopes of the higher mountains receive large rainfall totals, while crests above 2,500 m receive less than half that falling on the slopes.

The other areas receiving excessive rains include the Caribbean coast near southern Belize to Puerto Barrios, Guatemala, the Caribbean coast of Nicaragua at and south of Bluefields, the Caribbean coast of Panama near the Gulf of Los Mosquitos, the southeast corner of Panama, and the *southern* coast of Costa Rica.

While most of the rain-bearing disturbances come from the Caribbean, leading to larger rainfall on the Caribbean side, the reader must keep in mind that diurnal sea breezes provide their rainfall production ashore on the North Pacific Ocean side as well, with winds from the south or west. Drier areas, such as west of the Gulf of Fonseca, are believed to be partly caused by katabatic winds[15]. Also, the drier eastern side of the Peninsula of Azuero, Panama may be shielded from disturbances of North Pacific origin by the mountain range on the western half of the peninsula.

[15]Winds blowing down an incline, the opposite of anabatic wind (Huschke, 1959).

With only a couple of exceptions, all of Central America has two rainfall maxima, with generally higher totals on the Caribbean Sea side. The main dry season occurs in winter or early spring and is much more intense (drier) on the North Pacific Ocean side of Central America.

With the drier winter and spring, the North Pacific Ocean side has appreciable accumulation from June through October, yet with a relative minimum during the two summer months of July and August. This relative minimum is locally labeled the "varanillo"(little summer). While **all** months have a diurnal rainfall maximum between sunset and midnight, June and September have an additional rainfall accumulation[16] in the early afternoon (1200L-1600L). Thus the North Pacific side maxima are in June and September.

Again, while the Caribbean side has a not-so-dry late winter (as does the North Pacific Ocean side), the general pattern of its maxima consists of a summer maximum near June or July and another relative maximum in December.

Thunderstorms

While thunderstorms are a common occurrence in Central America, the two regions of maximum thunderstorm activity are (1) the Gulf of Fonseca (116 storm days[17] per year on Amapala) and (2) the center of the Canal Zone (196 storm days at Madden Dam). The minima are 37 at Chimax, in central Guatemala and a questionable **three** at Belize City.

Visibility

Portig (1976) reports that fog practically never occurs at sea and at coastal stations, but that inland stations occasionally have shallow fog in the morning that is rapidly dissipated by the sun. (However, one of the authors observed **heavy** coastal morning fog during a winter (dry season) approach to the Caribbean side of the Panama Canal in February 1963.)

The dry season has many days with haze, providing a real hazard for aircraft. However, **above** the haze, the trade wind inversion provides unlimited visibility. Furthermore, the Pacific side of Central America has the "best" and the "worst" visibilities, i.e., the Pacific side has a larger variation in visibility, than the Caribbean side.

Overall Weather

In winter and spring, i.e., the dry season, the steadily blowing trades produce generally fine weather. Of course, the incursions of cold air from North America (or the Gulf of Mexico) interrupt this fine weather, with less effect equatorward of Nicaragua. (GOES imagery, examined during 1988, verified these statements.)

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[16]From Portig(1976) data which is predominantly from San Salvador.

[17]While Portiq (1976) does not define *storm day*, Huschke (1959) defines a *thunderstorm day* as "...an **observational day** during which thunder is heard at the station. Precipitation need not occur".

Most of the winter rain for northern Honduras comes from the long-lasting rain and drizzle accompanying cold fronts reaching the mountains. Again these cold fronts tend to be dry on the Pacific Ocean side because of the foehn[18] effect. The cold north wind is called norte, norther, or tehuentepeco. While it can become destructively strong, it is often welcomed during the monotonous dry season. As mentioned earlier, the lowest temperatures occur when the wind subsides and cooling by nocturnal radiation follows.

While the first norther of the seasons tends to bring a distinct weather change, subsequent incursions become less potent. Accordingly, Portig (1976) states that it is difficult to determine the exact number of northers per season. Estimates run from 30–40 per year or less.

Chapel (1927), who has defined northers by wind rather than through weather patterns, studied the average conditions of six northers reaching Colon, Panama, noting that the wind nearly doubled in strength on the day of arrival, with a pressure rise **only** on the day of arrival, but with increased rainfall amounts for three days after arrival. While no rain may fall when a cold front passes, heavy downpours can occur where the front finally stalls. Such heavy rainfalls can be found on the Caribbean coastal area of southeastern Nicaragua.

However, the rainy season has more synoptically driven events than does the dry season. In the rainy season, they are manifest as hurricanes, tropical depressions, waves in the easterlies or even displaced fragments of the Intertropical Convergence Zone (ITCZ). Rainfall from hurricanes is considered beneficial in many areas, but hurricanes are **not** responsible for the rainfall maximum in the fall. Portig (1976) reports that "tropical lows or depressions occur at varying intensities all over region, and occasionally in the dry season"; moreover, personal communication[19] in 1986 revealed that development of a tropical depression near the Canal in December 1985 required immediate measures to control the water level of the Canal, before the depression moved slowly toward the northwest.

Local developments

Portig (1976) defines the "temporal" as a longlasting rain, with no, or little, electrical activity. While categorizing them as "local" is debatable, they are typical of two areas: the north coast of Honduras (caused by invasions of cold air from the north during the winter (dry season) and the Pacific Ocean coast of all of Central America. While continued research is needed, the temporals along the Pacific Ocean coast may often be tropical depressions moving slowly westward. Portig (1976) suggests that they may transform from "temporal"-lows into hurricanes, and vice versa. While the Pacific temporal may have hurricane-like spiral bands, its winds are generally light and moderate, without lightning and thunder, but its rainfall, covering a relatively large area, can cause water damage.

[18]Foehn—A warm, dry wind on the lee side of a mountain range, the warmth and dryness of the air being due to adiabatic compression upon descending the mountain slopes (Huschke, 1959).

[19]Conversation between Joe Corelli, Hydrologist of the Panama Canal Commission and one of the authors.

Portig (1976) further reports that "it is not possible to clearly distinguish between the temporals and temporal-like situations ('tiempo atemporalado' as the man on the street says), but a fair estimate calls for one or two temporals a year for each location on the North Pacific coast of Central America". The greatest probability is in September or October, with a secondary maximum in June.

As a local phenomena, the sea breeze may be strong enough at times to overcome the large-scale wind regime, blowing from the west in a typical trade wind area. For example, in western Panama, it can reach 30 km inland.

Squalls are frequent, and over water thunderstorms frequently generate waterspouts. Tornadoes are less frequent than waterspouts, and hail is rare, even in locations experjencing many thunderstorms. Hail has fallen on the Pacific Ocean side of Guatemala and in Panama, and snow falls on elevations above 3400 m in Guatemala (Portig, 1976).

1.3 National Climatologies

Following closer examination of Central America and its topography, this section will discuss the climate and terrain of each country. On the following two pages, Fig. 1.20 (The Diagram Group, 1985) with its shading, and Spanish names for mountain ranges and volcanoes, provides a better perspective of terrain elevation, while Fig. 1.21 (The Diagram Group, 1985) with its *larger* scale (compared to Fig. 1.1) displays the national boundaries of the seven countries more clearly.

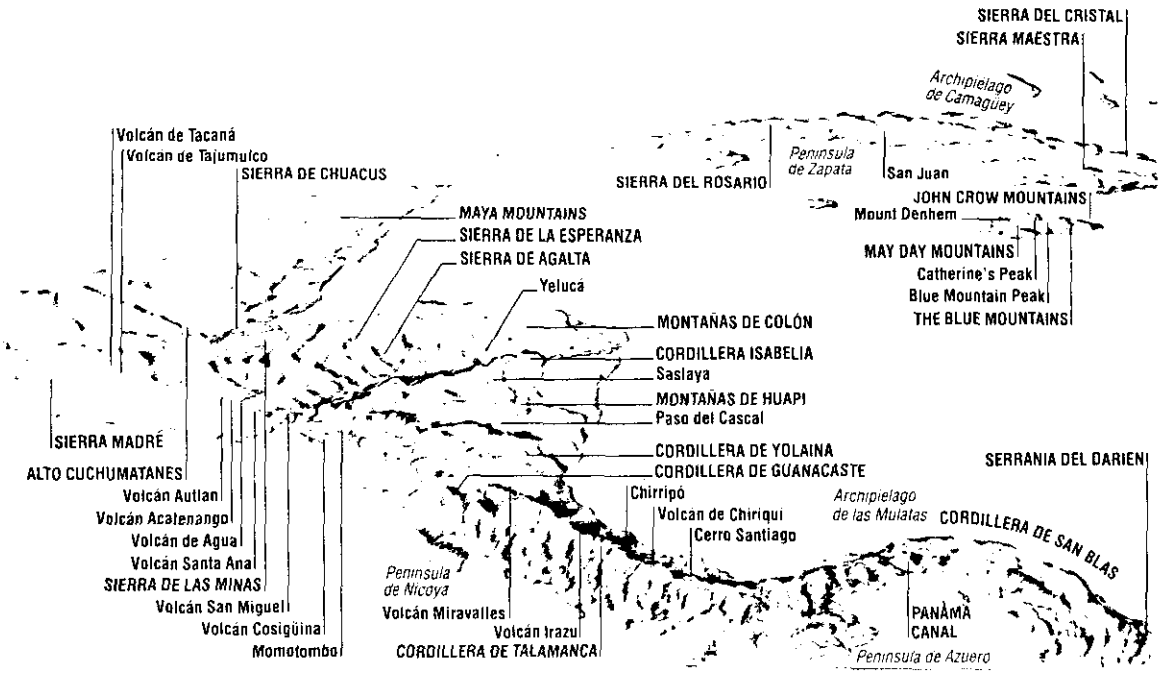

Figure 1.20: Topography of Central America (The Diagram Group, 1985)

Figure 1.21: Seven Countries of Central America (The Diagram Group, 1985)

1.3.1 Guatemala

Land

While having the most people of any nation in Central America, Guatemala is the third largest nation, equivalent to the size of Tennessee. In addition to bordering Mexico on the north and west, its Pacific coastline is located to the southwest. On its eastern border (starting from the north) is Belize, followed by a short Caribbean coastline, and then finally Honduras and El Salvador.

As depicted in Fig. 1.22, Guatemala has a rather narrow Caribbean coast to the east, but a fairly extensive Pacific Ocean coast to the south. While lagoons and sand bars extend the length of the gently curving Pacific coast, just inland are fertile coastal lowlands for about 25 miles. The coastal Pacific lowlands then give way to the highlands of the southern and central region, while the north is occupied by the plains of Petén.

Approximately two-thirds of the country is occupied by highlands with the main mountain range being a southeast extension of Mexico's Sierra Madre, paralleling the coast only about 40 miles inland. With many high volcanic peaks, some active, the inland highlands extend from 3500 - 8000 feet in elevation. Very near the western border and at 13,845 feet, the Tajumulco Volcano is the *highest* peak in Central America. But between volcanic peaks lie volcanic rich basins.

Guatemala's longest river, the Motagua, lies just north of the main mountain range and flows eastward to the Gulf of Honduras and the Caribbean Sea. From another valley, not far to the north, the Polochic River runs parallel to the Motagua, flowing into Guatemala's largest lake, Izabal, before reaching Amatique Bay in the Gulf of Honduras. While the sparsely populated limestone plains of Petén comprise most of northern Guatemala, the relatively low Maya Mountains extend into southern Belize. A narrow, fertile coastal plain exists along the short Caribbean coast (The Diagram Group, 1985).

Climate

General The cooling effects of both coasts and highlands provide a variety of climates within Guatemala. The coasts are hot and humid, about 80°F (27°C) throughout the year. Inland highlands are cooler; for example, at Guatemala City, at nearly 5000 feet above sea level, the average annual temperature is 64.4°F (18°C). The months of December and January are coolest.

The rainy season lasts from May to November—October, if you use Guatemala City rainfall, (not shown). While the Caribbean-facing slopes get rain almost all year, the Pacific coast receives heavy summer rain, but stays dry during the winter. Annual rainfall varies from 80 inches in the highlands to about half that amount in parts of eastern Guatemala (The Diagram Group, 1985).

Figure 1.22: Guatemala (The Diagram Group, 1985)

Rainy Season: May – October. The rainy season is characterized by mostly cloudy skies[20], with warm to hot temperatures, and frequent rain showers and thunderstorms. At night, the temperatures below about 3000 feet and at coastal locations fall to the mid to upper 70's (°F), then rises to the upper 80's or lower 90's during the afternoon. However, the upper plateau which includes Guatemala City, is cooler with lows near 55–60°F and highs 70–80°F. Rainfall, which is moderate on the interior plateau, increases to very heavy on seaward-facing mountain slopes and lower elevations. While most rain falls as brief showers, the "temporal" can bring low ceilings and visibilities, as well as continuous rain, for periods from 12 hours to 6 days.

Thunderstorm days occur in the lowlands at a frequency of 8–14 per month, with a considerably higher frequency on exposed mountain slopes. While the interior plateau has only 2–8 thunderstorm days per month (see monthly totals below), both the lowlands and interior plateau have a thunderstorm maximum in the midafternoon, with a secondary thunderstorm maximum found at coastal stations between midnight and sunrise. The thunderstorms may be accompanied by strong gusty winds and severe lightning. See Section 5 and Appendix C for tracks of tropical cyclones affecting Guatemala.

Flying weather: Poor to fair flying weather may be expected during the rainy season due to heavy cloud cover, rain and thunderstorms. Cloud-enshrouded mountain slopes naturally present a hazard to aircraft operations. See Appendix B for specific statistics at Huehuetenango and Puerto Barrios.

Terminal weather: Guatemala City/La Aurora Airport. While the terminal weather is fair to good, early morning fog may frequently restrict flying activity. Ceiling less than 300 feet and/or visibility less than 1 mile[21] occurs only 1–3 percent of the time, and thunderstorms are most frequent from mid-afternoon to early evening. Crosswinds greater than 15 knots and occur less than 1 percent of the time (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

GUATEMALA CITY	MAY	JUN	JUL	AUG	SEP	OCT
TEMPERATURE (°F)						
Absolute maximum	90	89	83	88	88	84
Mean maximum	80	76	76	77	76	74
Mean minimum	60	60	59	59	59	58
Absolute minimum	49	54	50	53	52	46
MEAN PRECIPITATION (INCHES)	9.2	10.1	8.0	7.4	10.4	6.0
MEAN NUMBER OF DAYS						
Precipitation	11	21	16	20	22	10
Thunderstorms	4	7	5	8	8	2
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0512	0509	0517	0526	0529	0532
Last light (local standard time)	1845	1856	1858	1847	1825	1804

[20]Clear = 0/10 sky cover, partly cloudy = 1/10–5/10, cloudy = 6/10–9/10 and overcast = 10/10.

[21]Henceforth, ceiling/visibility, e.g., 300/1 indicates "ceiling of 300 feet **and/or** visibility of 1 mile".

Dry Season: November – April. Contrasted to the rainy season, the dry season is characterized by only *partly* cloudy skies, and warm to hot temperatures. Precipitation is infrequent except in the northern lowlands and on the Caribbean slopes of mountains. While these two locations record minimum precipitation amounts during this season, they do not experience the very dry conditions that occur in the interior and on the Pacific mountain slopes. Morning fog occurs frequently in the interior highlands and valleys. While temperatures in the lowlands range from 65–75°F in the morning to 80–90°F in the afternoon, the interior highlands warm from morning lows of 35–40°F to highs of 65–70°F. Above 7000 feet elevation, subfreezing temperatures are not uncommon. Precipitation occurs only 0–3 days per month on the Pacific mountain slopes and in the interior highlands. Snowfall is infrequent, confined to the highest mountain peaks; and thunderstorms are uncommon in the dry season. However, on the Caribbean mountain slopes and northern lowlands, rainfall occurs 3–20 days per month, with the greatest amount of rainfall occurring on the mountain slopes; nonetheless, thunderstorms are still infrequent. Not only may mid-latitude cold fronts penetrate as far south as Guatemala (if not further) with their associated strong, gusty northerly winds and one or two days of cloudy skies and rain, but tropical cyclones are still a possibility on the Caribbean coast during November.

Flying weather: Generally good except in the Caribbean lowlands and on mountain slopes. The weather begins to deteriorate along the North Pacific coast in February, and by April the ceiling/visibility is less than 5000/6 as often as 90 percent of the time; however, elsewhere less than 5000/6 occurs only 20–40 percent of the time. On the plateau due to fog near sunrise, 1500/3 occurs as often as 60 percent of the time, while 500/1 occurs as often as 15 percent (see Appendix B for Huehuetanango and Puerto Barrios data).

Terminal weather: Guatemala City/La Aurora Airport. Generally good, except that ceiling/visibility less than 300/1 occurs as often as 12 percent of the the time, likely around sunrise (early morning fog). Thunderstorms are infrequent, and as in the rainy season, occurrence of crosswinds greater than 15 knots is less than 1 percent (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

GUATEMALA CITY	NOV	DEC	JAN	FEB	MAR	APR
TEMPERATURE (°F)						
Absolute maximum	86	84	86	89	92	91
Mean maximum	73	74	75	77	80	82
Mean minimum	55	54	53	53	56	58
Absolute minimum	45	41	42	41	45	47
MEAN PRECIPITATION (INCHES)	0.8	0.4	0.1	*	0.3	0.7
MEAN NUMBER OF DAYS						
Precipitation	3	2	1	1	4	3
Thunderstorms	1	*	*	*	1	2
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0540	0556	0608	0604	0549	0527
Last light (local standard time)	1753	1759	1815	1828	1834	1838

(NOTE: * = less than 0.05 inch or 0.5 day, as appropriate)

1.3.2 Belize

Land

Belize, lying in the southeastern portion of the Yucatan Peninsula, has Mexico on its northern border, Guatemala on its western border as well as on its very narrow southern border, while it has the Caribbean Sea (actually the Gulf of Honduras) along its entire eastern boundary. While its neighbor Guatemala is the *most* populated, Belize has the smallest population of the seven Central American nations. However, it is the second *smallest* nation—only El Salvador is smaller—having an area just smaller than the state of New Hampshire.

As depicted in Fig. 1.23, Belize has a much larger north-south dimension (174 miles) than east-west dimension (68 miles at its widest). It can be divided into three regions: the northern lowlands, southern uplands and the coast. Most of the northern lowlands are swampy, lying less than 200 feet above sea level. In the southern uplands are found the hills and valleys of both the Maya Mountains, and its northeast extension, the Cockscomb Mountains. Considerably lower than Guatemala's Tajumulco, Belize's highest mountain is Victoria Peak at 3681 feet. The rivers, all running eastward and draining into the Caribbean Sea are: Hondo (forming the northern border with Mexico), New, Belize, Monkey, Sarstoon (forming most of Belize's southern border, with Guatemala) and others. Inland from its low and swampy coast, lie numerous lagoons. In addition to many small, low islands (cays), the world's second-largest barrier reef lies 10–40 miles offshore (The Diagram Group, 1985).

Climate

General Belize's climate is subtropical, with onshore trade winds. While the *mean* temperature at Belize City on the coast ranges from 74° in December to 85° in July, inland days are hotter and nights are cooler. Annual rainfall ranges from 50 inches in the flatter northern lowlands to 170 inches in the more mountainous south. While hurricanes can sweep westward over Belize from the Caribbean Sea, droughts are possible (The Diagram Group, 1985).

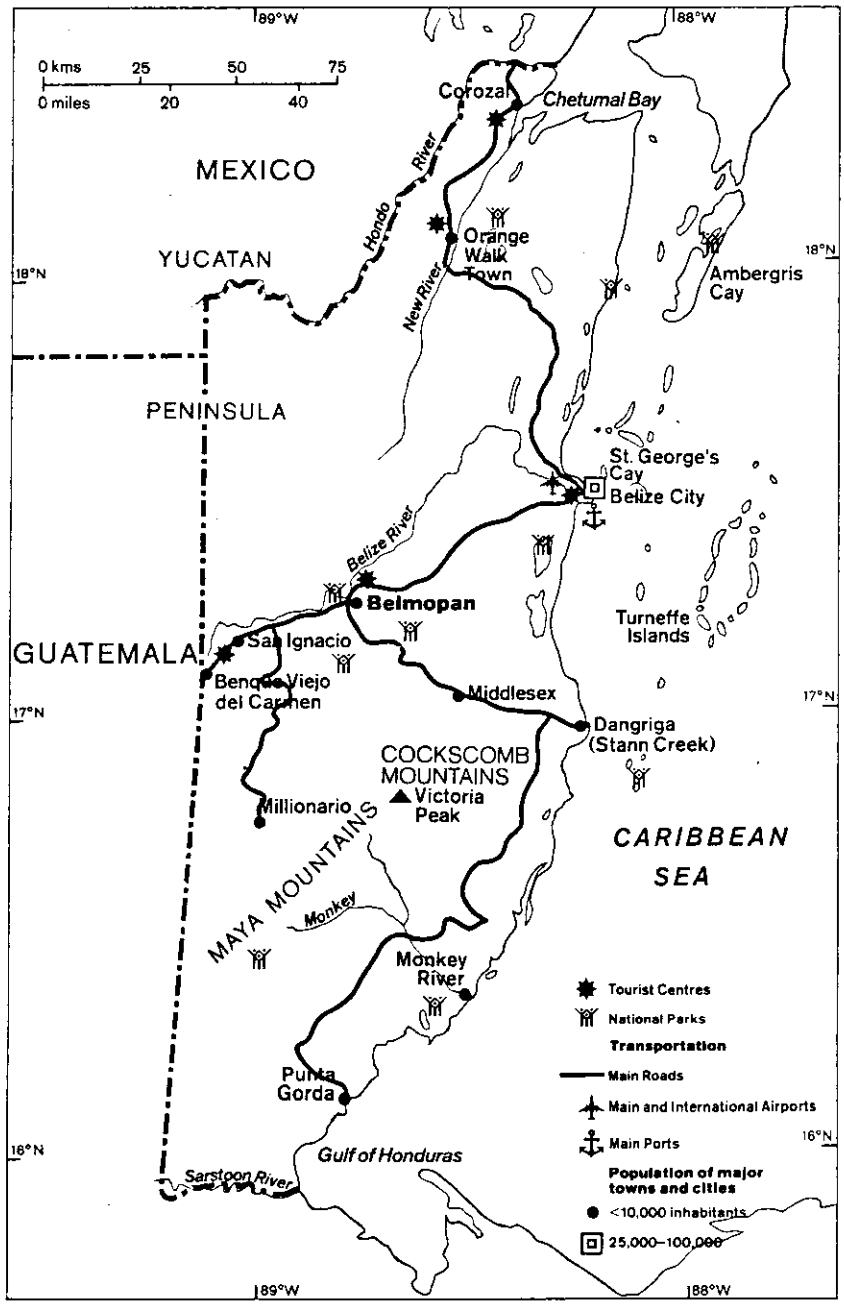

Figure 1.23: Belize (The Diagram Group, 1985)

The climate of Belize will *not* be divided into a rainy season and a dry season as is done with the other countries. However, while the climate is treated as an *annual* one which is hot, humid and cloudy, rainfall is generally moderate to heavy from May through January (with the monthly maximum in October at Belize City; see next page), with a reduction of cloudiness and rainfall during February and March.

More specifically, rainfall is extremely heavy from only June through September in the southern one-quarter of the country. While mean cloudiness is 55–70 percent from April through January, it is slightly less than 50 percent in February and March.

As noted below, for Belize City, mean maximum temperatures are in the upper 80's (°F) during the summer and lower 80's during the winter, while mean minimum temperatures are in the 70's from March through October and in the 60's from November through February.

Again, as noted below, the thunderstorm frequency is greatest from June through September. While thunderstorms are quite uncommon in northern Belize, their frequency increases southward. Additionally, they occur during the morning along the coast, but during the afternoon inland. Mean surface winds are northeast to east, 8–15 kt. Being the country farthest north, Belize frequently experiences a day or two of rain and strong northerly winds ushered in by mid-latitude cold fronts, from November through March.

Affected by tropical storms and hurricanes from May through November, the monthly probability of having at least one tropical storm and/or hurricane strike Belize ranges from 5 to 20 percent with the greatest probability in September (see Section 5).

Flying weather: Fair to good, although flying weather may be restricted by early morning fog, heavy rainfall or thunderstorms. The percentage frequency of ceiling/visibility less than 5000/6 ranges from 25–50 percent, while 1500/3 ranges from 10–20 percent (see Appendix B for specific ceiling/visibility statistics for Belize City).

Terminal weather: Belize City. Hot and humid, with moderate to heavy rainfall. Mean relative humidities lie between 75 and 90 percent. While rainfall is expected 4–18 days per month, the heaviest rainfall accumulation is from June through January. Ceiling/ visibility is less than 300/1 about 1 percent of the time, mostly during early morning hours. Visibility is restricted primarily by rain, haze/smoke and early morning fog. Runway crosswinds are greater than 15 kt during 1–3 percent of the time (USAFETAC, 1985)

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

BELIZE CITY	JAN	FEB	MAR	APR	MAY	JUN
TEMPERATURE (°F)						
Absolute maximum	90	93	98	99	97	97
Mean maximum	82	83	85	87	88	88
Mean minimum	68	69	72	74	75	76
Absolute minimum	50	49	50	55	57	62
MEAN PRECIPITATION (INCHES)	5.7	2.7	1.6	2.4	5.0	9.1
MEAN NUMBER OF DAYS						
Precipitation	12	6	4	4	7	14
Thunderstorms	0	*	0	0	1	4
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0604	0558	0540	0515	0458	0454
Last light (local standard time)	1802	1817	1825	1832	1841	1853

	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE (°F)						
Absolute maximum	95	96	97	95	95	93
Mean maximum	88	88	89	86	84	82
Mean minimum	76	76	75	73	69	68
Absolute minimum	63	61	60	58	52	46
MEAN PRECIPITATION (INCHES)	7.6	7.3	9.5	12.4	9.8	7.2
MEAN NUMBER OF DAYS						
Precipitation	18	16	18	15	13	14
Thunderstorms	2	4	5	1	*	0
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0503	0513	0519	0524	0535	0552
Last light (local standard time)	1855	1842	1817	1753	1740	1745

(NOTE: * = less than 0.5 day)

1.3.3 Honduras

Land

Honduras occupies the *upper* portion of the "knee" of Central America. As Central America's second-largest nation (only Nicaragua is larger), Honduras is a little larger than the state of Tennessee. While Guatemala and El Salvador form its western border, and Nicaragua its long southeastern boundary, Honduras has a short stretch of Pacific coastline in the south, compared with a long northern Caribbean coast. Its small Pacific coast borders the Gulf of Fonseca, while the extensive Caribbean coast includes the Gulf of Honduras in the west (see Fig. 1.24).

With its wedge shape, Honduras is about 400 miles from west to east, but only about 180 miles from south to north. Honduras, although nearly two-thirds occupied by uplands and mountains, has no *active* volcanoes as do its neighbors, but its highest peak is Cerro de las Minas (9,347 feet) in the west. Mountain ranges approach the northern coast at an angle, with one range continuing submerged out to sea and reappearing as the Islas de la Bahía (Bay Islands) chain. While much of the northern coast is rimmed by a lowland of rich clay and loam soils, the Caratasca Lagoon, a swampy lowlands, occupies the northeast corner, along the Mosquito Coast[22]. Rivers flowing north, including the Ulúa in the northwest, form fertile valleys. To the south, the Gulf of Fonseca, which contains an archipelago of nearly 300 tiny islands, is surrounded by a narrow lowland (The Diagram Group, 1985).

Climate

General While the coastal lowlands are hot and humid, the upland interior is cooler and much drier. Although average temperatures in the highlands at 7000 feet are only in the high 50's (°F), they reach the mid 80's on the coast. Tegucigalpa, the capital, has an annual temperature range of only 11°F. While the northeast is the wettest region of the country, where onshore winds are associated with up to 110 inches of rain per year, some inland valleys receive only 40 inches (The Diagram Group, 1985).

[22]A strip along the Caribbean Sea (including both northeastern Honduras and the entire east coast of Nicaragua) named for its Miskito Indians.

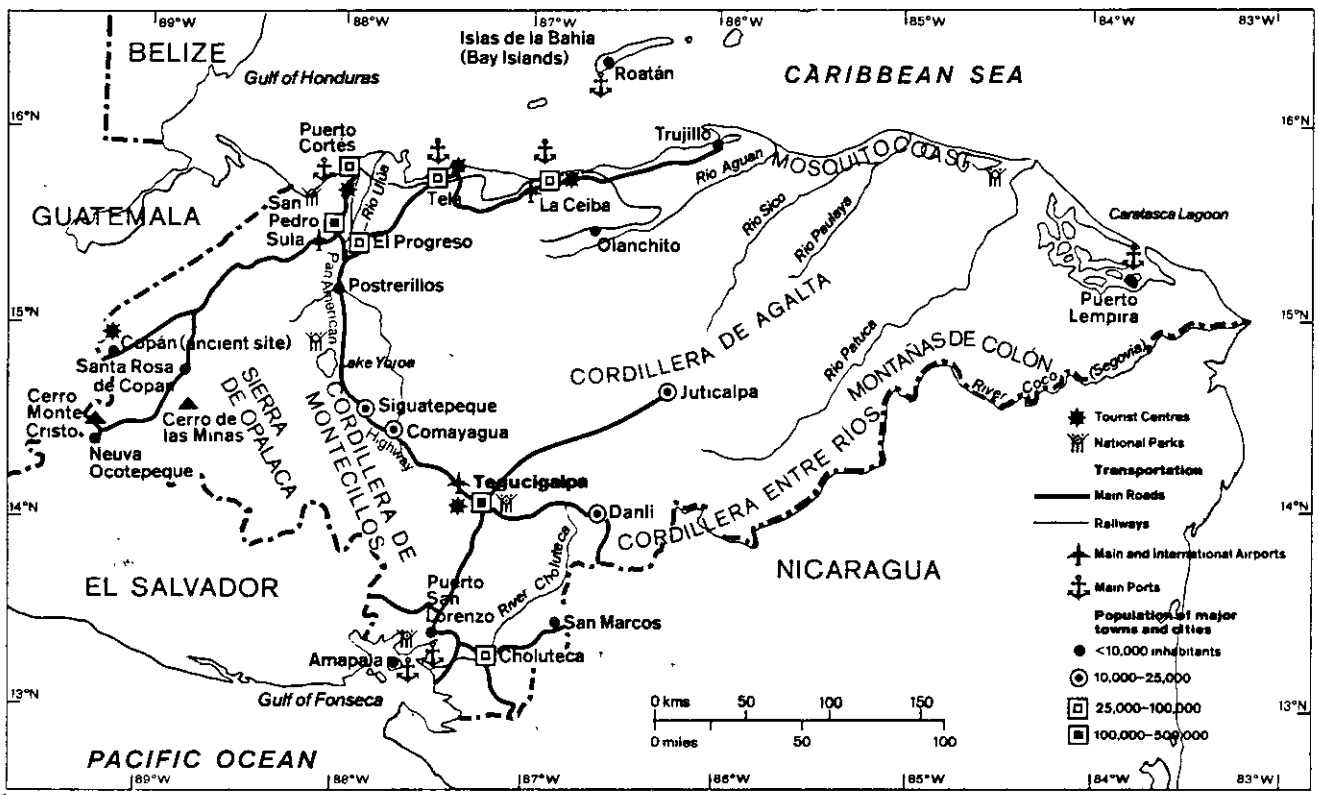

Figure 1.24: Honduras (The Diagram Group, 1985)

Rainy Season: May – October. During this season, the weather is characterized by mostly cloudy skies and hot temperatures, with frequent rain showers and thunderstorms. Surprisingly, however, along the north coast on the Gulf of Honduras some stations record the minimal precipitation at this time of year. While precipitation amounts on the Caribbean coast are often very heavy, only moderate amounts are expected in the interior. Mean monthly cloudiness varies between 50 and 85 percent. Depending upon elevation, mean minimum temperatures vary between the 60's and the upper 70's (°F). Note that the data given below are for Tegucigalpa (3,304 feet). Maximum monthly temperatures range from the upper 80's to the lower 90's, with particularly hot low lying Pacific coast stations. Thunderstorms occur with greater frequency at coastal stations. Surface winds are normally northerly or northeasterly at 6–10 kt. See Section 5 for details concerning tropical storms or hurricanes that primarily affect the Caribbean coastal areas.

Flying weather: Usually good, except in the vicinity of thunderstorms. Ceiling/visibility less than 5000/6 occurs 25–45 percent of the time, while less than 1500/3 occurs 5–10 percent, and less than 500/1 occurs 1-6 percent. Icing and turbulence are not expected except near rain showers and thunderstorms; however, early morning fog can be a problem at mountain stations (see Appendix B for ceiling/visibility statistics at several coastal and inland cities).

Terminal weather: Tegucigalpa. Generally good. Ceiling/visibility less than 300/1 rarely occurs; yet fog forms on 14–22 mornings per month, but rarely restricts visibility below 3 miles. As indicated below, thunderstorms occur on 6–12 days per month, normally during early evening. Occurrence of crosswinds greater than 15 kt is 1–3 percent, normally during late afternoon and early evening (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

TEGUCIGALPA	MAY	JUN	JUL	AUG	SEP	OCT
TEMPERATURE (°F)						
Absolute maximum	94	90	89	91	90	88
Mean maximum	85	82	81	83	83	80
Mean minimum	64	65	64	63	63	63
Absolute minimum	49	56	55	54	55	52
MEAN PRECIPITATION (INCHES)	5.7	6.3	3.5	3.9	7.2	5.4
MEAN NUMBER OF DAYS						
Precipitation	11	17	15	14	19	16
Thunderstorms	9	12	7	7	11	6
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0459	0457	0505	0513	0516	0518
Last light (local standard time)	1831	1841	1844	1833	1812	1751

Dry Season: November – April. The weather during this season is characterized by *partly* cloudy skies and infrequent rainfall, yet warm to hot temperatures. **However**, in the eastern part of the country near the Caribbean Sea the rainy season does not end until December, and **moreover**, the north coast, on the Gulf of Honduras, receives its maximum rainfall at this time. Rain occurs 5–20 days per month along the northern coast, but generally less than 5 days per month in the interior (see Tegucigalpa data below) and on the Pacific coast. Mean monthly cloudiness in the interior is about 55–75 percent, and 30–50 percent on the Pacific coast, where offshore winds dominate. While minimum temperatures range from 55 to 75 (°F), maximum temperatures range from 70 to 85 (°F). Along the narrow Pacific coast, extremely high temperatures (over 100°F) occur daily. Thunderstorms occur 2–6 days per month in November and December (less in Tegucigalpa, see below), but less frequently in later months. Mean surface winds are north to northeast at 8–15 kt (i.e., stronger than in the rainy season). Extratropical cold fronts occasionally reach the north coast causing one to two days of rain and strong northerly winds.

Flying weather: Usually good. Ceiling/visibility less than 5000 feet and/or 6 miles occurs 15–45 percent, while less than 1500/3 occurs 1–5 percent, and less than 500/1 rarely occurs. Along the north coast, aircraft icing can occur above the freezing level in stratified cloudiness (see Appendix B for ceiling/visibility statistics at several cities).

Terminal weather: Tegucigalpa. Good. Ceiling/visibility less than 300/1 seldom occurs; morning fog is common, but it seldom restricts visibility significantly. While precipitation occurs 2–9 days per month, thunderstorms are rare except in April (see below). Occurrence of crosswinds greater than 15 kt is 2–5 percent (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

TEGUCIGALPA	NOV	DEC	JAN	FEB	MAR	APR
TEMPERATURE (F)						
Absolute maximum	91	88	89	91	93	96
Mean maximum	78	77	77	80	84	86
Mean minimum	60	58	57	57	58	62
Absolute minimum	48	47	39	43	46	48
MEAN PRECIPITATION (INCHES)	1.7	0.5	0.5	0.2	0.4	1.1
MEAN NUMBER OF DAYS						
Precipitation	9	6	4	2	2	4
Thunderstorms	1	0	*	0	1	3
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0527	0542	0554	0551	0535	0514
Last light (local standard time)	1740	1746	1803	1816	1821	1824

(NOTE: * = less than 0.5 day)

1.3.4 El Salvador

Land

While El Salvador is the most *densely* populated, it is the smallest nation in Central America—about the size of the state of Massachusetts.

As indicated in Fig. 1.25, El Salvador, unlike the other six Central American nations, has no Caribbean coast. With Guatemala to the west and Honduras to the north and east, El Salvador has the Pacific Ocean coast as its entire southern border. Note, however, that only the Gulf of Fonseca separates its southeastern corner from the western tip of Nicaragua.

The shape of El Salvador is roughly rectangular, 160 miles from west to east, and 60 miles from north to south. Although not immediately evident, El Salvador can be divided into four regions, running *roughly* the length of the country. The four regions are, from south to north, the Pacific lowlands, the southern mountains, the plateau and the northern mountains.

While only 12 percent of El Salvador consists of coastal lowlands and hills, lagoons form part of the southeast coastline. Another third of the nation is formed by the southern mountain chain, at the western end of which is Santa Ana, with a peak at 7,812 feet. Even the nation's largest lake, Llopango, lies in an extinct volcanic crater. While some of its more than 20 volcanoes are active, with the commensurate expectation of earthquakes, volcanic ash and lava provide the nation's richest soils. The plateau, at an elevation averaging 2000 feet and comprising more than two-thirds of the country, is drained by the deep valleys of the Rivers Lempa and San Miguel in the eastern half of El Salvador. Finally, the northern mountains cover about 15 percent of the nation; here El Salvador's highest peak, Cerro El Pital (8,956 feet), is located (The Diagram Group, 1985).

Climate

General The nation's temperature varies with altitude. While the coast is hot and humid, the high inland regions are cooler. The capital San Salvador, at 2,290 feet, has an annual average temperature of only 73°F, with a small range of 5.4°F. While the hottest months are April and May, the coolest months are December through February. The country's annual rainfall is 72 inches; however, the higher mountains receive more and the valleys less than this average (The Diagram Group, 1985).

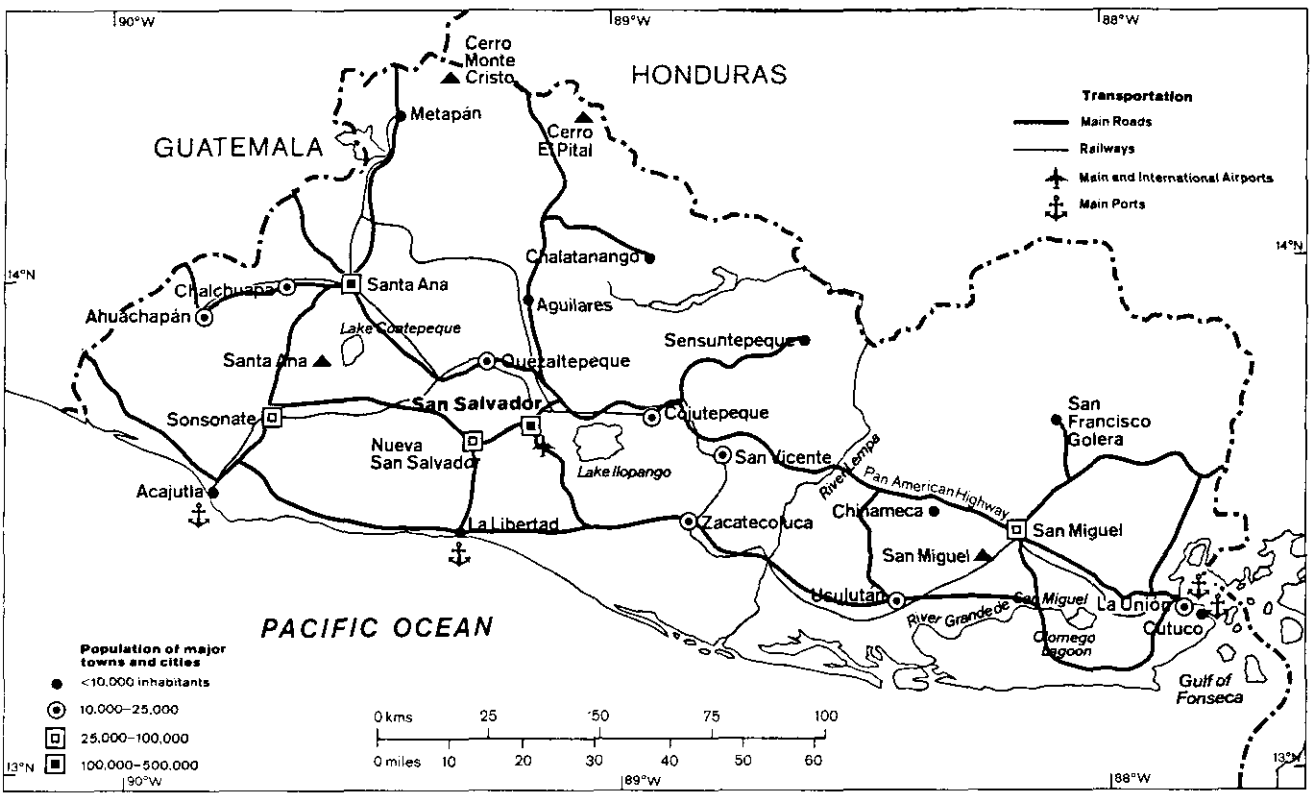

Figure 1.25: El Salvador (The Diagram Group, 1985)

Rainy season: May – October. Heavy rainfall is expected in warm and cloudy weather, with an occasional tropical storm or hurricane. Cloudy skies dominate with: clear skies, 1–3 percent; partly cloudy, 15–35 percent; cloudy, 50–70 percent; and overcast, 10–20 percent of the time. Rain is expected 10–25 days per month, usually associated with thunderstorms. However, gusty surface winds in excess of 16 kt are expected less than 1 percent of the time, with gale force winds (33 kt) rare. The monthly probability of tropical cyclones and/or hurricanes affecting El Salvador increases from 15 percent in May through July to 30 percent in August through October (see Section 5).

Flying weather: Fair to Poor. The percentage frequencies of ceiling/visibility are : less than 5000 feet and/or 6 miles, 10–25 percent; less than 1500/3, 5–10 percent; and less than 500/1, 1-2 percent. Not only are thunderstorms and rain very heavy at times, but heavy rain showers and early morning fog can restrict flying conditions. (See Appendix B for ceiling/visibility statistics at Acajutla and San Salvador.)

Terminal weather: San Salvador. The weather is warm and cloudy, with numerous thunderstorms and heavy rain showers, leading to ceiling/visibility less than 300/1 for 1-2 percent of the time. Runway crosswinds in excess of 15 kt are expected only about 1 percent of the time. Gusty surface winds in excess of 16 kt are expected less than 1 percent, with gale force winds a rarity. Visibility is obstructed 5–10 percent due primarily to haze/smoke and early morning fog; however, during May visibility is obstructed 30 percent of the time due to haze/smoke, dust and early morning fog (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

SAN SALVADOR	MAY	JUN	JUL	AUG	SEP	OCT
TEMPERATURE (°F)						
Absolute maximum	103	98	98	98	99	101
Mean maximum	91	87	89	89	87	87
Mean minimum	67	66	65	66	66	65
Absolute minimum	58	56	58	60	53	54
MEAN PRECIPITATION (INCHES)	7.4	12.7	12.5	11.7	12.5	9.0
MEAN NUMBER OF DAYS						
Precipitation	13	20	22	21	21	16
Thunderstorms	13	17	18	18	18	10
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0507	0505	0513	0521	0524	0526
Last light (local standard time)	1838	1848	1851	1840	1819	1759

Dry season: November – April. The weather is hot and dry (see data below), with clear to partly cloudy skies. Partly cloudy skies dominate with: clear skies, 10–35 percent; partly cloudy, 45–50 percent; cloudy 20–40 percent; and overcast, 1–5 percent of the time. Rain occurs only 1–5 days per month, and is usually associated with a thunderstorm. Visibility is obstructed 5–15 percent of the time during November through March, but this percentage increases to 40 percent in April, with the primary restrictions to visibility being haze/smoke and dust. While gusty surface winds in excess of 16 kt are expected 5 percent of the time, gale force winds are rare. Tropical cyclones and/or hurricanes are rare during this period (see Section 5).

Flying weather: Generally good. The percentage frequencies of ceiling/visibility are: less than 5000 feet and/or 6 miles, 5–10 percent, November through March and 25 percent in April; less than 1500/3 miles, 1–2 percent; and less than 500/1, rare. However, early morning fog can restrict flying activities in the highlands (see Appendix B for ceiling/visibility statistics at Acajutla and San Salvador).

Terminal weather: San Salvador, El Salvador. The weather is hot and dry with ceiling/visibility less than 300/1 a rarity. Precipitation is expected 1–5 days per month (see data below), usually associated with a thunderstorm. Primary restrictions to visibility are haze/smoke and dust, leading to obstruction to visibility 5–10 percent from November through February, 15 percent in March, and increasing to 40 percent in April; however, visibility rarely goes below 3 miles. While gusty runway crosswinds in excess of 15 kt are expected about 1–2 percent of the time, gusty surface winds in excess of 16 kt are expected 5 percent of the time, but gale force winds are rare (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

SAN SALVADOR	NOV	DEC	JAN	FEB	MAR	APR
TEMPERATURE (°F)						
Absolute maximum	102	101	101	103	105	104
Mean maximum	87	89	90	92	94	93
Mean minimum	63	61	60	60	62	65
Absolute minimum	49	47	45	49	45	54
MEAN PRECIPITATION (INCHES)	1.6	0.4	0.2	0.2	0.4	2.1
MEAN NUMBER OF DAYS						
Precipitation	5	1	1	1	1	5
Thunderstorms	5	1	1	1	5	5
CIVIL TWILIGHT (15th of month)						
First light (local standard time)	0534	0549	0601	0558	0543	0522
Last light (local standard time)	1748	1755	1811	1823	1828	1831

1.3.5 Nicaragua

Land

Nicaragua is the largest nation of Central America—a little larger than the state of New York. With the Caribbean Sea to its east and the Pacific Ocean to its west, Nicaragua occupies a "mid" position within Central America (see Fig. 1.26). Only two countries have borders with Nicaragua, Honduras along the long boundary to the north, and Costa Rica to the south.

The shape of Nicaragua somewhat resembles a triangle formed by the Honduran border, the Caribbean coast, and finally a line produced by the Pacific coast and the Costa Rican border. The country's highest mountain Pico Mogotón (6,913 feet) lies in the northwest near the Honduran border. From the Honduran border southward there are three separate mountain chains ("cordilleras") in the center of the country: Cordillera Isabella running nearly parallel to the Honduran border, next Cordillera De Darien running east-west, and finally Sierra De Amerique (also known as Cordillera Chontaleña) lying to the northeast of Lake Nicaragua. There are many rivers, with River Coco forming much of Nicaragua's border with Honduras, while the San Juan, likewise, forms much of the southern border with Costa Rica.

To the east of these central mountain chains lies Nicaragua's Mosquito coast, one of the broadest Caribbean lowlands in Central America. This coast extends approximately 336 miles, including deltas, sandbars and lagoons, with offshore reefs[23] and islands ("cayos").

Lake Nicaragua, Central America's largest lake, lies southwest of the mountain chains. This lake and smaller Lake Managua, lie parallel to the Pacific coast but inland of about 40 volcanoes (some active) which also form a line parallel to the Pacific coastline. The Pacific coast of Nicaragua extends from the Gulf of Fonseca to the Salinas Bay. Volcanic ash here, as well as in the central valleys, has produced fertile soil (The Diagram Group, 1985).

Climate

General The lowlands are hot and humid. On the Pacific coast, average annual temperature is 81°F, on the Caribbean coast, 79°F; however, mountains, in the northern portion of the country, have lower temperatures, i.e., about 64°F.

With 150 inches of rainfall per year, the Caribbean side of Nicaragua has one of the highest rainfalls in Central America. However, with the prevailing winds (primarily *katabatic*) blowing from the northeast, the Pacific side of Nicaragua receives only about half that amount with a more marked dry season from January through April (The Diagram Group, 1985).

[23]For further oceanographic details, see Section 4.

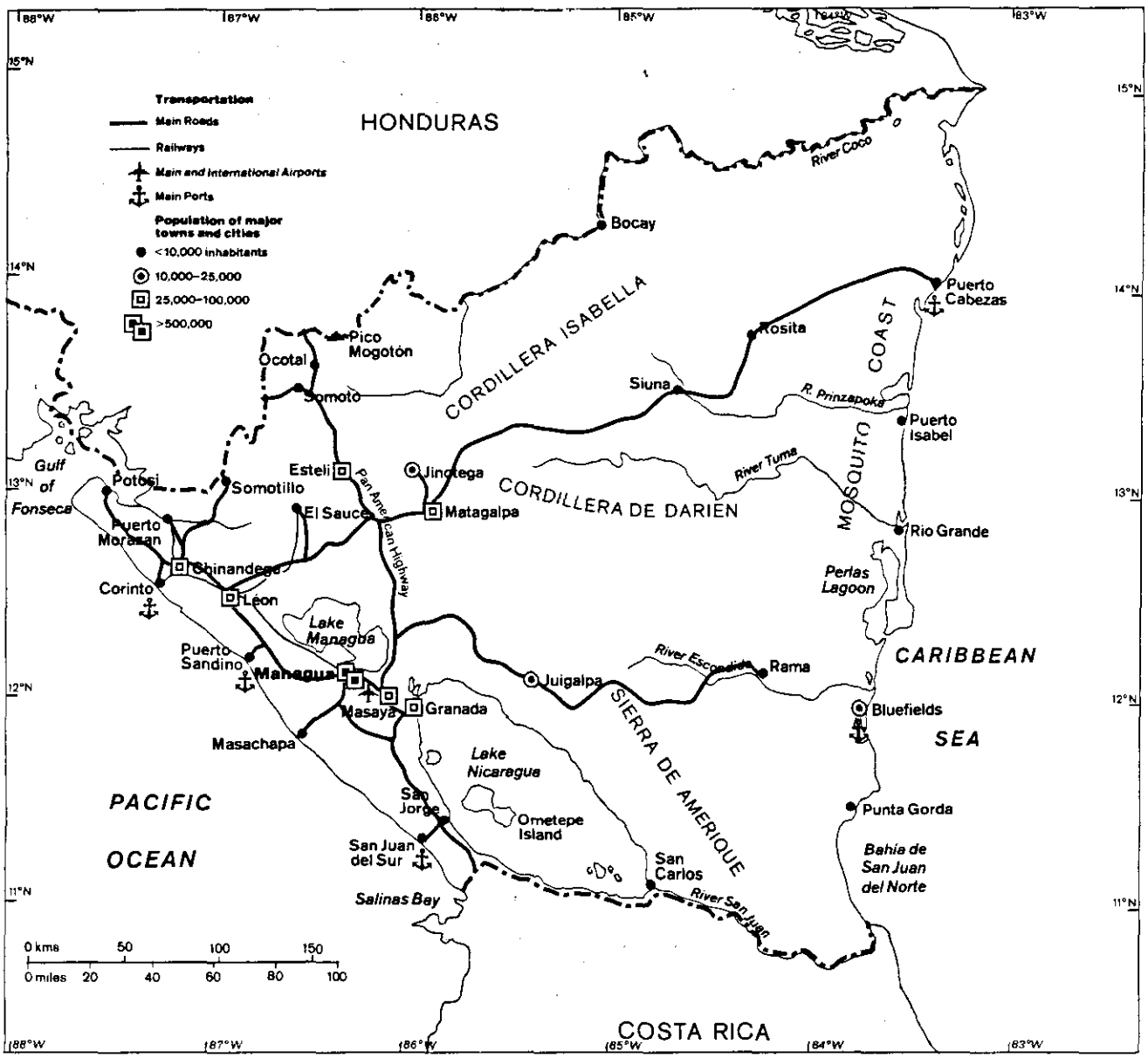

Figure 1.26: Nicaragua (The Diagram Group, 1985)

Rainy season: June – October

These months are characterized by frequent precipitation and heavy cloudiness. Nighttime temperatures are quite warm, then climb from the low 70's (°F) in the early morning to the 80's or low 90's by afternoon. Mean sky cover, primarily in the form of low clouds, ranges from 70 to 80 percent. Precipitation, which is smaller in the interior, is most frequent along the Caribbean lowlands where the monthly average is 10–26 inches. Precipitation can be expected 17–30 days per month, and thunderstorms are frequently accompanied by strong, gusty winds and violent lightning. Visibilities are generally good, except along the coast. Fog, heavy rain showers, haze and/or smoke restrict coastal region visibilities to less than 6 miles, 10–20 days per month. Winds, averaging less than 15 kt, are usually calm during the night and then increase during the day, with 55 kt possible during severe thunderstorms. The average monthly probability of a tropical storm and/or hurricane affecting Nicaragua ranges from 15 to 25 percent (see Section 5).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

MANAGUA	JUN	JUL	AUG	SEP	OCT
TEMPERATURE (°F)					
Absolute maximum	95	92	93	94	94
Mean maximum	88	88	89	89	88
Mean minimum	73	73	73	73	72
Absolute minimum	69	70	70	69	66
MEAN PRECIPITATION (INCHES)	8.2	3.6	5.1	6.8	6.3
MEAN NUMBER OF DAYS					
Precipitation	13	11	10	11	10
Thunderstorms	13	13	10	14	7
CIVIL TWILIGHT (15th of month)					
First light (local standard time)	0457	0504	0511	0513	0513
Last light (local standard time)	1833	1837	1827	1807	1748
BLUEFIELDS					
TEMPERATURE (°F)					
Absolute maximum	94	93	92	94	94
Mean maximum	87	85	87	89	88
Mean minimum	73	73	73	72	71
Absolute minimum	66	67	62	66	64
MEAN PRECIPITATION (INCHES)	19.8	26.2	21.5	12.3	13.6
MEAN NUMBER OF DAYS					
Precipitation	N/A	N/A	N/A	19	20
Thunderstorms	*	*	*	*	*

(* = less than 0.5 day)
(N/A = data not available)

Flying weather: Fair to good. The heavy rainfall along the Caribbean coast, such as at Bluefields (see totals on previous page), produces ceiling/visibility less than 5000 feet and/or 6 miles for 1–15 percent of the time, with less than 1500/3, 1–3 percent. While heavy rain showers and thunderstorms are frequent throughout the country, they are especially prevalent along the coast. Tops of thunderstorms often reach 60,000 feet, some being reported as high as 80,000 feet. Severe turbulence is expected with these storms, plus mountain-wave turbulence presents a hazard to flying west of the mountain ridges, i.e., "downwind" of the ridges (see Appendix B for ceiling/visibility statistics for Bluefields, Chinadega, Managua and Puerto Cabezas).

Terminal weather: Good. At Managua, the percentage frequency of ceiling/visibility less than 300/1 is 0–1 percent; at Bluefields it is 1–2 percent. While mean winds are less than 10 kt during the evening, winds are 15 kt in the afternoon, with even stronger winds associated with thunderstorms, tropical storms and/or hurricanes. Heavy rain showers, fog, smoke and/or haze provide the primary restrictions to visibility (USAFETAC, 1985).

Transitional months: November – December

November and December are the transitional months between the rainy and dry seasons. The hot temperatures and cloudy skies continue; however, there is a general decline in precipitation (particularly notice Managua's rainfall on the following page). While morning temperatures (high 60's (°F)) are slightly cooler than the rainy season, the afternoons still warm to the low 90's. Mean sky cover (20–40 percent) is lower in the inland portion of Nicaragua, but the coastal regions remain near 70 percent. Likewise, the mean precipitation is much less inland than on the coast (compare Managua and Bluefields), with the mean monthly rainfall ranging from 2–20 inches over the country. Thunderstorm days reduce to only 4–6 per month. Fog, smoke and/or haze reduce visibilities to less than 2.5 miles approximately 1 day per month. Usually occurring in the afternoon, winds greater than 16 kt are expected 1–2 days per month. While the probability of at least one tropical storm and/or hurricane affecting Nicaragua is 10 percent in November, tropical cyclones in December are rare (see Section 5).

Flying weather: Fair to good. Despite the larger rainfall at Bluefields, the percentage frequency that ceiling/visibility is less than 5000 feet and/or 6 miles is approximately 5 percent, but at Managua, ceiling/visibility less than 5000/6 is about 15 percent. Expectation of ceiling/visibility less than 1500/3 is 1 percent at both stations. Turbulence is anticipated in thunderstorms; additionally, low-level clear air turbulence is sometimes present on hot, sunny days (see Appendix B for ceiling/visibility statistics for several cities).

Terminal weather:

Managua (Las Mercedes), Nicaragua. Warm and cloudy conditions prevail, with light rain storms and occasionally gusty surface winds. Skies are clear only 5 percent of the time; partly cloudy to cloudy skies dominate 70–80 percent, with overcast, 10–25 percent. Visibility is generally good, as early morning fog occurs less than one day per month. Rain is expected seven days in November, but its frequency decreases to only two days in December (see data below). While gusty winds are expected 2–5 percent of the time, gale force winds are rare and ceiling/visibility less than 300/1 has not been observed.

Bluefields, Nicaragua. Cloudy and rainy, with clear skies a rarity. Skies are partly cloudy to cloudy 75–80 percent; overcast, 20–25 percent. Although rainfall is expected 22 days per month (see data below), the ceiling/visibility rarely goes below 300/1. While gusty surface winds are expected 2–5 percent of the time, gale force winds are a rarity (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

MANAGUA	NOV	DEC
TEMPERATURE (°F)		
Absolute maximum	92	91
Mean maximum	88	87
Mean minimum	71	70
Absolute minimum	64	59
MEAN PRECIPITATION (INCHES)	1.2	0.3
MEAN NUMBER OF DAYS		
Precipitation	7	2
Thunderstorms	1	*
BLUEFIELDS		
TEMPERATURE (°F)		
Absolute maximum	93	93
Mean maximum	86	85
Mean minimum	70	69
Absolute minimum	62	62
MEAN PRECIPITATION (INCHES)	15.3	15.7
MEAN NUMBER OF DAYS		
Precipitation	22	22
Thunderstorms	1	*
CIVIL TWILIGHT (15th of month)		
MANAGUA (LAS MERCEDES)		
First light (local standard time)	0520	0534
Last light (local standard time)	1839	1745

(* = less than 0.5 day)

Dry season: January – April

Distinguished by a marked decline in rainfall (especially note the small precipitation for Managua, below), this season is characterized by hot days, cooler nights and partly cloudy skies. Of course, the Caribbean coast remains an exception where cloudiness and rain persist throughout the year (see the precipitation totals for Bluefields, below). Temperatures range from near 70°F at night to the low 90's during the afternoon, although the afternoon temperatures at Bluefields are not quite so high. Mean sky cover is lower on the Pacific coast and inland (40–50 percent), but, it is near 70 percent along the Caribbean coast. Whereas much of the country experiences only 0.5 inch to 2.0 inches of rainfall, totals reach a maximum near 10 inches along the Caribbean coast, with rain occurring as often as 23 days of the month. Visibility is generally good, decreasing to 2.5 miles only one–three days per month, although visibility is restricted by haze/smoke near industrial centers. While wind speeds average 10–12 kt, gusty surface winds generally occur as often as six days per month. (See Section 5 for hurricane data.)

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

MANAGUA	JAN	FEB	MAR	APR
TEMPERATURE (°F)				
Absolute maximum	92	93	94	98
Mean maximum	88	89	91	94
Mean minimum	69	70	72	73
Absolute minimum	62	63	67	68
MEAN PRECIPITATION (INCHES)	*	*	*	*
MEAN NUMBER OF DAYS				
Precipitation	2	2	1	2
Thunderstorms	0	0	0	0
CIVIL TWILIGHT (15th of month)				
First light (local standard time)	0547	0545	0531	0511
Last light (local standard time)	1802	1813	1817	1818
BLUEFIELDS				
TEMPERATURE (°F)				
Absolute maximum	90	90	91	93
Mean maximum	85	85	87	88
Mean minimum	69	69	71	72
Absolute minimum	60	61	62	62
MEAN PRECIPITATION (INCHES)	10.5	5.1	3.2	2.9
MEAN NUMBER OF DAYS				
Precipitation	22	15	12	11
Thunderstorms	0	0	0	0

(* = less than 0.05 inch)

Flying weather: Fair to good. Bluefields on the Caribbean coast experiences ceiling/visibility less than 5000 feet and/or 6 miles, 1–3 percent of the time; and less than 1500/3, less than 1 percent of the time. In the west, Managua experiences ceiling/visibility less than 5000/6, 10–15 percent; and less than 2000/2.5, approximately 1 percent of the time (see Appendix B for ceiling/visibility statistics at several cities).

Terminal weather:

Managua (Las Mercedes), Nicaragua. Warm and cloudy with gusty surface winds and *little* precipitation. Skies are clear 10–15 percent of the time, with rain expected only 1–2 days per month (see data on preceding page). The visibility is restricted by haze and/or smoke 45–50 percent, but rarely goes below 6 miles. While gusty surface winds generally exist 5–10 percent of the time, gale force winds are experienced less than 1 percent of the time. Ceiling/visibility less than 300/1 is a rarity.

Bluefields, Nicaragua. Cloudy and **rainy**. Partly cloudy to cloudy skies (85–90 percent) dominate, with overcast skies 10-15 percent of the time and clear skies a rarity. Mean monthly rainfall, totally 10.5 inches (22 rainfall days) in January, decreases to 2.9 inches (11 rainfall days) in April (see data on preceding the page). Gusty surface winds are expected 2–5 percent of the time; however, gale force winds are rare. Visibility is restricted by haze/smoke 25–30 percent of the time, but it rarely goes below 6 miles. While, early morning fog forms occasionally, it dissipates rapidly after sunrise (USAFETAC, 1985).

Transitional month: May

May is the transition month between the dry and rainy seasons. Rainfall and cloudiness both increase in all parts of Nicaragua. Cloudy skies dominate with: clear 1–5 percent, partly cloudy 20–25 percent, cloudy 40–60 percent and overcast 15–35 percent of the time. While rain occurs on 10–17 days, thunderstorms occur only 2–4 days, depending on location. As expected, skies are cloudiest and rainfall heaviest on the Caribbean side of mountains. While winds in excess of 16 kt are expected approximately 5 percent of the time, gale force winds are rare. The monthly probability of a tropical storm and/or hurricane affecting Nicaragua, being near zero during the dry season, increases to 5 percent (see Section 5).

Flying weather: Fair to good. At Managua, ceiling/visibility is less than 5000 feet and/or 6 miles, 30 percent of the time; less than 1500/3, approximately 1 percent; and less than 500/1, near zero. Heavy rainfall and cloudiness may restrict flying, particularly on the eastern side of the mountains. Additionally, mountain-wave turbulence is possible over and near mountains (see Appendix B for ceiling/visibility statistics for several cities).

Terminal weather: Generally good. While ceiling/visibility is less than 300/1, approximately 1–2 percent of the time; rain is, nonetheless, frequent and heavy at times. Fog is expected only 1 percent of the time, primarily during the early morning hours. At Managua, the visibility is restricted 60 percent of the time by haze and/or smoke. While gusty winds greater than 16 kt are expected 5 percent of the time, gale force winds are a rarity (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

MANAGUA (LAS MERCEDES)	MAY
TEMPERATURE (°F)	
Absolute maximum	98
Mean maximum	93
Mean minimum	74
Absolute minimum	65
MEAN PRECIPITATION (INCHES)	3.1
MEAN NUMBER OF DAYS	
Precipitation	10
Thunderstorms	2
BLUEFIELDS	
TEMPERATURE (°F)	
Absolute maximum	94
Mean maximum	87
Mean minimum	74
Absolute minimum	67
MEAN PRECIPITATION (INCHES)	13.6
MEAN NUMBER OF DAYS	
Precipitation	17
Thunderstorms	0
CIVIL TWILIGHT (15th of month)	
MANAGUA (LAS MERCEDES)	
First light (local standard time)	0458
Last light (local standard time)	1824

1.3.6 Costa Rica

Land

Costa Rica, Central America's fifth-largest nation, is slightly larger than Vermont and New Hampshire combined. Long and narrow, it has a mountainous spine running from Nicaragua in the north to Panama in the southeast (see Fig. 1.27). Its long irregular Pacific coastline measures 631 miles compared with a much shorter and more straight Caribbean shore of only 132 miles.

While the swampy Caribbean coastal plain forms 30 percent of Costa Rica, the mountainous spine consists of three mountain ranges (cordilleras), from the northwest to the southeast: Guanacaste, Central and Talamanca. It's highest mountain peak Chirripó (12,529 feet) is found in the southeastern portion of the country in the Talamanca range. Within these ranges, the mountains are flanked by fertile tablelands. The soil has been made rich by volcanic ash, such as that which fell from the eruption of Irazú (in central Costa Rica, see Fig. 1.27) in 1963-1964.

On the irregular, low Pacific coast are found both the hilly Nicoya and Osa peninsulas. While the River El Coco (also known as the Rio Grande) flows from central Costa Rica westward into the Gulf of Nicoya, the country's largest river is the navigable San Juan, shared in part by Nicaragua, which flows into the Caribbean Sea (The Diagram Group, 1985).

Climate

General Typical of Central America, Costa Rica has hot, humid coasts, but cooler uplands. Average temperatures range from above 80°F near the coast, 69°F in the capital San José, at 3,800 feet, to only 59°F near 7,500 feet. The "temperate" or "cold" zones start at about 1,000 feet, but are lower on the Pacific than on Caribbean slopes.

Not only on the Caribbean coast, but also on the southern Pacific coast, rainfall totals over 126 inches per year. In particular, on the Caribbean side, northeast winds can provide 300 days with rain—the orographically produced cloudiness on the east side of the mountain ranges is frequently evident on satellite imagery (The Diagram Group, 1985).

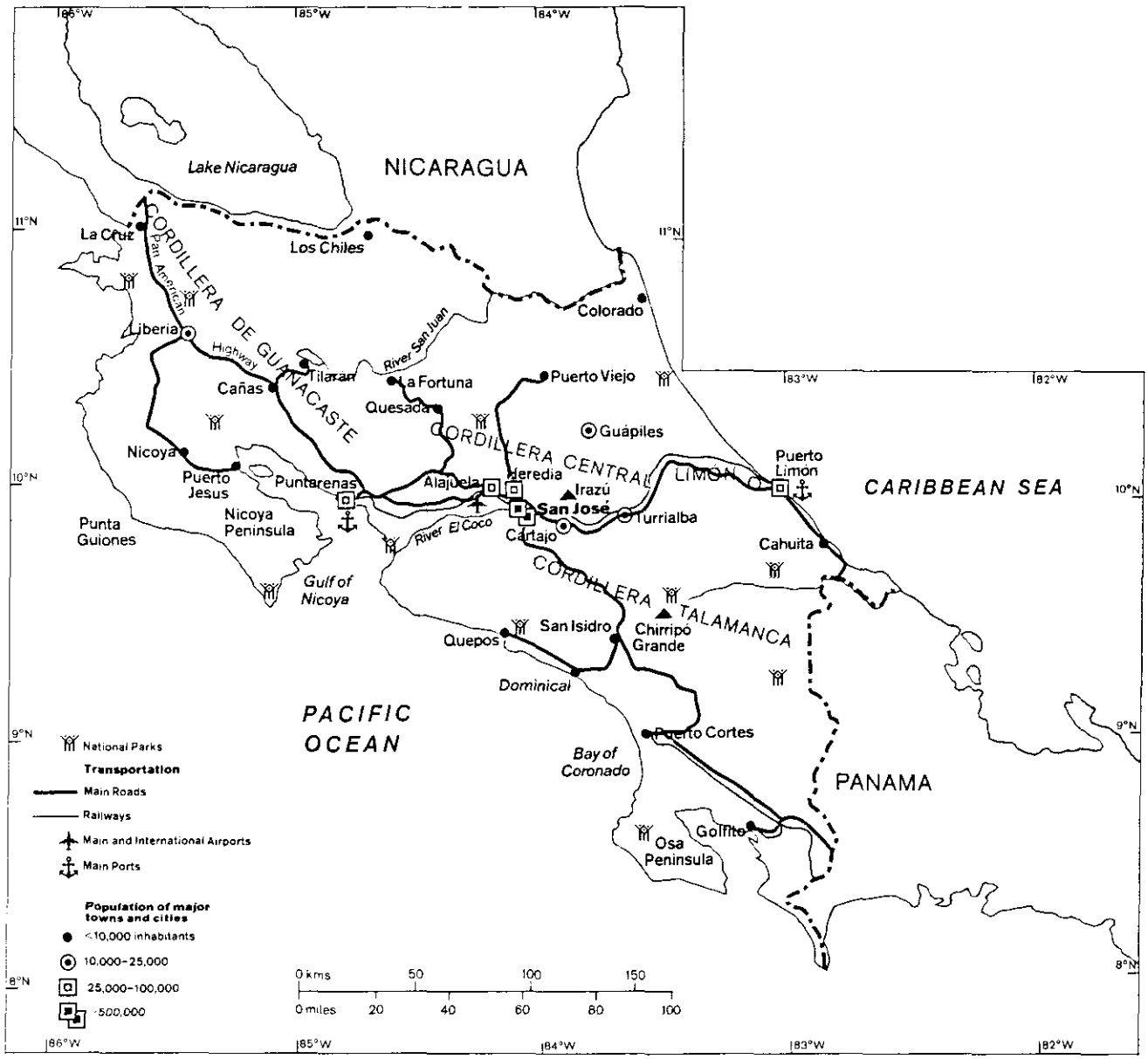

Figure 1.27: Costa Rica (The Diagram Group, 1985)

Rainy season: May – November. This is the rainy season with moderate to heavy rain, cloudy skies and warm temperatures. Mean rainfall averages 10 to even 26 inches per month at some locations. While thunderstorms are expected on 5–10 days per month; skies are clear less than 5 percent of the time; partly cloudy to cloudy, 40–55 percent; and overcast, 50–60 percent. Weather generally improves in November, as the dry season approaches (see Section 5 for the rather unlikely possibility of tropical storm or hurricane threat).

Flying weather: Poor to fair due to rainfall and cloudiness. Ceiling/visibility is less than 5000 feet and/or 6 miles between 10 to 25 percent of the time; less than 1500/3, 5 to 10 percent of the time. Thunderstorms are numerous, as noted below (see Appendix B for ceiling/visibility statistics for Liberia, Puerto Limón, Puntarenas and San José).

Terminal weather: San José/El Coco International, Costa Rica. The weather is warm, cloudy, windy and rainy. While the skies are: clear, less than 5 percent of the time; partly cloudy, 10–20 percent; cloudy, 25–30 percent; and overcast, 40–60 percent, the frequency that the ceiling/visibility is less than 300/1 is only 2 percent. Whereas winds greater than 16 kt are present 5–25 percent of the time, their maximum frequency is realized in July, with their minimum in September-October. Nevertheless, gale force winds are expected less than 1 percent of the time (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

SAN JOSÉ/EL COCO	MAY	JUN	JUL	AUG	SEP	OCT	NOV
TEMPERATURE (°F)							
Absolute maximum	88	92	84	85	86	85	84
Mean maximum	80	79	77	78	79	77	77
Mean minimum	62	62	62	61	61	60	60
Absolute minimum	54	56	54	56	56	55	52
MEAN PRECIPITATION (INCHES)	9.3	9.6	7.6	7.4	12.4	14.0	4.8
MEAN NUMBER OF DAYS							
Precipitation	18	21	23	23	26	26	15
Thunderstorms	7	5	5	5	8	6	1
CIVIL TWILIGHT (15th of month)							
First light (local standard time)	0453	0453	0500	0506	0505	0504	0509
Last light (local standard time)	1812	1821	1824	1816	1758	1741	1733

Dry season: December – April. The weather, dry and windy in the mountains and western Costa Rica in accordance with the season's name, is, nonetheless, cloudy with **moderate to heavy rainfall** on the Caribbean or eastern side of the mountains. Although rainfall averages 1 inch or less in the mountains and Pacific coast regions, it remains high on the eastern side, 5–22 inches. Thunderstorm occurrence varies from 1–3 days per month (see data below). While occasional outbreaks of cold air from North America provide below-normal temperatures and fresh breezes, normal temperatures average in the mid 60's to low 70's (°F) during the morning hours and then reach the mid 80's to low 90's in the afternoon. High winds can be expected in mountainous regions during all months; moreover, isolated mountain locations may be slightly cooler than mentioned earlier.

Flying weather: Generally good. Although the mountains and western Costa Rica generally have clear to partly cloudy skies, flying may be restricted in eastern Costa Rica in clouds and moderate to heavy rain showers. At San José/El Coco International, ceiling/visibility is less than 5000 feet and/or 6 miles approximately 5 percent of the time, while ceiling/visibility less than 1500/3 is approximately 1 percent of the time (see Appendix B for ceiling/visibility statistics at several cities).

Terminal weather: San José/El Coco International, Costa Rica. While warm and windy conditions exist with clear to partly cloudy skies 45–75 percent of the time, cloudiness increases in April with the approach of the rainy season. Rainfall is expected only 1–2 days per month during the driest months, January through March (see data below). Fog is rare, but visibility is occasionally restricted by haze and/or smoke. The ceiling/visibility is less than 300/1 less than 1 percent of the time. Note that winds greater than 16 kt occur 50–65 percent of the time; gale force winds, 5–10 percent of the time. Runway crosswinds greater than 15 kt occur 15–20 percent of the time (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

SAN JOSÉ/EL COCO	DEC	JAN	FEB	MAR	APR
TEMPERATURE (°F)					
Absolute maximum	87	87	88	91	89
Mean maximum	75	75	76	79	79
Mean minimum	58	58	58	59	62
Absolute minimum	49	49	51	50	53
MEAN PRECIPITATION (INCHES)	1.3	0.2	0.6	0.6	1.7
MEAN NUMBER OF DAYS					
Precipitation	7	1	2	2	6
Thunderstorms	0	*	*	1	3
CIVIL TWILIGHT (15th of month)					
First light (local standard time)	0522	0535	0535	0523	0505
Last light (local standard time)	1741	1757	1807	1808	1808

(* = less than 0.5 day)

1.3.7 Panama

Land

Panama is the fourth largest and southernmost of the nations of Central America. It is bordered on the west by Costa Rica and on the east by Colombia, with the Caribbean Sea and North Pacific Ocean forming its northern and southern shores, respectively. While Panama is the most narrow country of Central America, its coastline is the longest of any of the seven nations. At its most narrow width Panama is only 31 miles across (see Fig. 1.28); however, its Pacific coastline extends for 760 miles, and its Caribbean coastline is 470 miles long.

Low mountain ranges run the length of the country, reaching the greater heights in the west, including the country's highest peak, the volcano Chiriquí, with an elevation of 11,411 feet. The mountain range shown as Serranía de Tabasara (see Fig. 1.28) is also known as Cordillera Central. While three-fifths of Panama is mountainous, between parallel mountain ranges lie fertile valleys and plains, in addition to the low-lying, sometimes swampy, coastal strips. Located in the eastern half of the country are the chief rivers: the Chagres, near the canal; the Chepo; and the Tuira, with its source in Colombia. Its only large lake, Gatún, is man-made.

Obvious from Fig. 1.28, its Pacific coast is much indented, with the Azuero Peninsula forming the western side of the Gulf of Panama. While the country's southeastern coast is on the Gulf of Panama in the Pacific Ocean, much of the northwestern coastline is on the Mosquito Gulf in the Caribbean Sea. The eastern side of the Gulf of Panama contains the Pearl Island archipelago, while its largest island, Coiba, lies in the Pacific Ocean to the west of the Azuero Peninsula.

The Panama Canal cuts across[24] the center of Panama, from northwest to southeast (The Diagram Group, 1985).

[24]Geography students are often surprised to learn that the Pacific entrance to the Panama Canal is *east* of the Caribbean (or Atlantic) entrance to the canal.

Climate

General The climate of Panama is generally tropical and rainy. While lowland temperatures average over 80°F, uplands are cooler at 66°F or less. Along the Caribbean coast and in the high mountains, more than 120 inches of rain falls per year; however, parts of the Pacific coast around the Gulf of Panama have less than 60 inches per year. Panama is considered to be outside the "hurricane belt" (The Diagram Group, 1985).

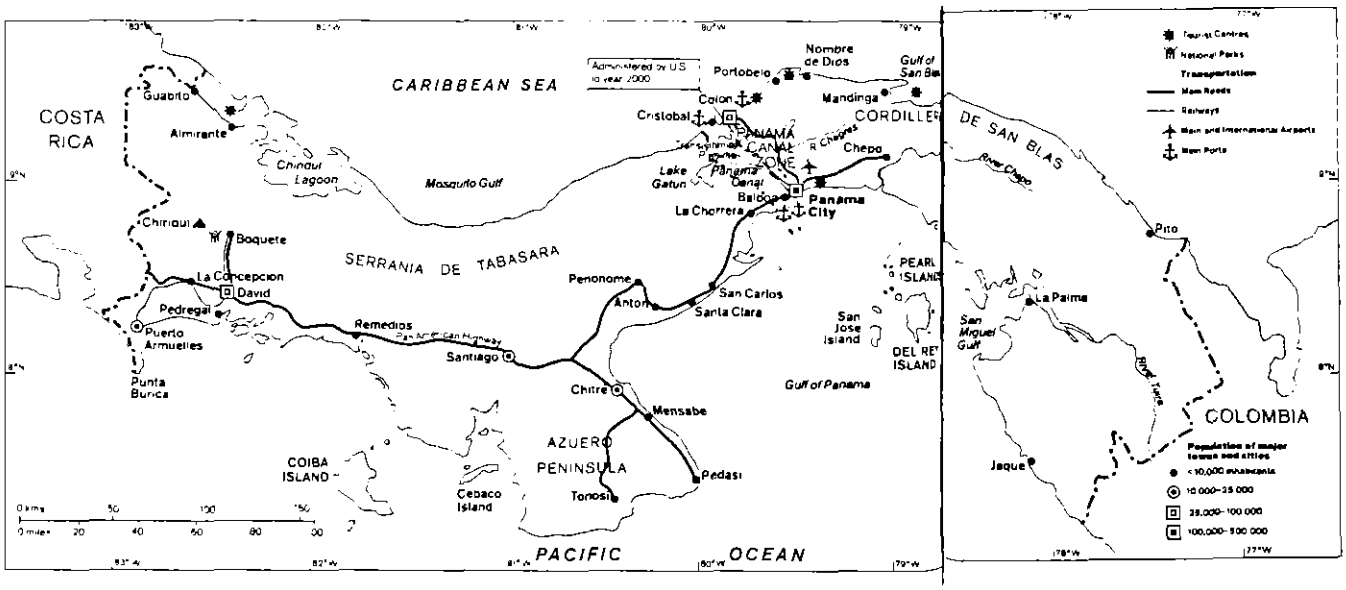

Figure 1.28: Panama (The Diagram Group, 1985)

Summer: June – August. During this season[25], the Intertropical Convergence Zone (ITCZ) passes to the north of Panama. The passage of the ITCZ is marked by an increase in precipitation, but there is a decrease as the ITCZ moves farther north. The typical weather in Panama consists of cloudy skies, high humidity, very warm temperatures and frequent afternoon showers and thunderstorms. Maximum temperatures are near 90°F along the coasts and 70°F–80°F in the mountains; whereas, minima are generally in the low 70's near the coast and mid 50's in the mountains. Mean cloudiness is a relative large 70–95 percent, and the average relative humidity is near 85 percent. Precipitation is likely 15–25 days per month, with thunderstorms 10–15 days per month. Gale force winds are a rarity.

Flying weather: While ceiling/visibility less than 5000 feet and/or 6 miles occurs *only* 10–30 percent of the time along the southern coast, ceiling/visibility less than 5000/6 occurs 40–65 percent of the time along the northern coast and over the mountain ranges. Similarly, ceiling/visibility less than 1500/3 occurs 2–12 percent of the time along the southern coast, but 15–35 percent along the northern coast or mountain ranges. Finally, ceiling/visibility less than 500/1 occurs 1–2 percent along the southern coast, yet 2–10 percent along the northern coast and mountain ranges. Expect late afternoon thunderstorms to affect any late afternoon flying operations; however, conditions normally improve at night. (See Appendix B for ceiling/visibility statistics for Fort Sherman, Howard Air Force Base and Rio Hato.)

Terminal weather:

Panama City/Torrijos International. While ceiling/visibility less than 300/1 occurs only 1–5 percent of the time, the most likely time is in the afternoon. Thunderstorms (about 17 or 18 days per month, see data on following page) provide the greatest problem (USAFETAC, 1985).

[25]Unlike the other six countries of Central America, with their rainy season and dry season, the proximity and effects of the Intertropical Convergence Zone (ITCZ) dictate the use of the more classical four seasons for Panama.

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

PANAMA CITY/TORRIJOS INTERNATIONAL	JUN	JUL	AUG
TEMPERATURE (°F)			
Absolute maximum	95	95	97
Mean maximum	87	88	86
Mean minimum	75	74	74
Absolute minimum	69	69	68
MEAN PRECIPITATION (INCHES)	7.9	7.6	7.5
MEAN NUMBER OF DAYS			
Precipitation	21	21	22
Thunderstorms	17	17	18
CIVIL TWILIGHT (15th of month)			
First light (local standard time)	0537	0544	0549
Last light (local standard time)	1901	1905	1905

CHANGUINOLA INTERNATIONAL *			
TEMPERATURE (°F)			
Absolute maximum	93	93	93
Mean maximum	89	88	88
Mean minimum	73	73	73
Absolute minimum	69	68	69
MEAN PRECIPITATION (INCHES)	7.9	11.3	9.3
MEAN NUMBER OF DAYS			
Precipitation	18	21	18
Thunderstorms	13	17	17

(*Changuinola is near the northwest Caribbean coast, just east of Guabito.)

Autumn: September – November. The autumn marks the return southward of the ITCZ. The table on the next page indicates a secondary precipitation maximum in October for Panama City, but in November for Changuinola. This season generally has the most precipitation, highest mean relative humidity and lowest wind speed. Maximum temperatures are in the mid to high 80's (°F) along the coast, but only in the 70°F–80°F range in the mountains. Both relative humidity averages (87 percent) and mean cloud cover (70 to 95 percent) are high. While precipitation occurs on 22–27 days per month, thunderstorms can be expected 10–20 days per month. Gale force winds remain extremely rare.

Flying weather: Ceiling/visibility below 5000 feet and/or 6 miles occurs 5–25 percent of the time along the Pacific coast, but 15–40 percent along the Caribbean coast and on the continental divide. Less than 1500/3 occurs 3–10 percent of the time along the Pacific coast, however, 1–25 percent along the Caribbean coast and on the continental divide. While ceiling/visibility less than 500/1 occurs less than 1 percent along the southern coast, 500/1 occurs about 3 percent along the northern coast and on the continental divide. Afternoon showers and thunderstorms produce low ceilings that may restrict flight operations. (See Appendix B for ceiling/visibility statistics for several stations.)

Terminal weather:

Panama City/Torrijos International. While ceiling/visibility less than 300/1 occurs only 1–4 percent of the time, thunderstorms are numerous during this season occurring an average of 18 days in October (see data on the following page) (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

PANAMA CITY/TORRIJOS INTERNATIONAL	SEP	OCT	NOV
TEMPERATURE (°F)			
Absolute maximum	95	95	94
Mean maximum	85	85	85
Mean minimum	75	74	74
Absolute minimum	69	69	66
MEAN PRECIPITATION (INCHES)	7.5	11.6	10.2
MEAN NUMBER OF DAYS			
Precipitation	23	24	22
Thunderstorms	15	18	10
CIVIL TWILIGHT (15th of month)			
First light (local standard time)	0547	0545	0549
Last light (local standard time)	1839	1823	1817

CHANGUINOLA INTERNATIONAL *			
TEMPERATURE (°F)			
Absolute maximum	94	94	93
Mean maximum	89	89	89
Mean minimum	73	72	71
Absolute minimum	58	59	58
MEAN PRECIPITATION (INCHES)	5.1	5.5	10.1
MEAN NUMBER OF DAYS			
Precipitation	14	16	18
Thunderstorms	15	13	9

(*Changuinola is near the northwest Caribbean coast, just east of Guabito.)

Winter: December – February. Winter (although such a seasonal title does not seem appropriate to mid-latitude dwellers) in Panama is the start of the dry season—more evident at Panama City than at Changuinola (see precipitation totals, on the following page). During this season, skies are partly cloudy, and temperatures remain high with windy conditions. The ITCZ moves far to the south of Panama, permitting the northeast winds to dominate (see Fig. 1.4). Maximum temperatures are in the high 80's (°F) along the coasts, and near 70°F in the central mountains. Minimum temperatures lie in the low 70's (°F) along the coast, but in the range 46°F to 59°F in the central mountains. While mean cloudiness in 50–70 percent, higher values are found along the northern coast (note the greater rainfall at Changuinola, on the following page) and in the mountains. Relative humidity values range from 50–90 percent, also highest in December and along the northern coast. Precipitation occurs mainly from afternoon and evening showers and thunderstorms: 5–15 days per month along the southern coast; and 10–25 days per month in the mountains and along the northern coast. However, thunderstorms are at a minimum averaging 0–5 days per month. While winds 17 kt or greater occur 5–20 percent of the time in January and February, gale force winds are rare, occurring only 2 percent of the time.

Flying weather: Fair to good. Ceiling/visibility below 5000 feet and/or 6 miles occurs 2–12 percent of the time on the southern coast, but 10–30 percent over the continental divide and the northern coast. Similarly, ceiling/visibility less 1500/3 occurs about 1 percent of the time over the southern coast, yet 5–15 percent over the mountains and northern coast. Ceiling/visibility less than 500/1 rarely occurs. The least favorable flying weather occurs in the late afternoon due to shower activity (see Appendix B for ceiling/visibility statistics at several stations).

Terminal weather:

Panama City/Torrijos International. Good. Ceiling/visibility less than 500/1 occurs less than 1 percent of the time, with the worst flying conditions in late afternoon. Thunderstorm frequency, highest in December, is much smaller in January and February (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

PANAMA CITY/TORRIJOS INTERNATIONAL	DEC	JAN	FEB
TEMPERATURE (°F)			
Absolute maximum	94	94	95
Mean maximum	87	88	89
Mean minimum	73	72	73
Absolute minimum	64	64	64
MEAN PRECIPITATION (INCHES)	5.6	1.5	0.9
MEAN NUMBER OF DAYS			
Precipitation	15	8	5
Thunderstorms	4	1	0
CIVIL TWILIGHT (15th of month)			
First light (local standard time)	0603	0616	0616
Last light (local standard time)	1825	1840	1849

CHANGUINOLA INTERNATIONAL #			
TEMPERATURE (°F)			
Absolute maximum	92	96	91
Mean maximum	87	87	87
Mean minimum	71	70	71
Absolute minimum	66	65	65
MEAN PRECIPITATION (INCHES)	13.4	9.3	6.2
MEAN NUMBER OF DAYS			
Precipitation	21	17	14
Thunderstorms	2	*	0

(#Changuinola is near the northwest Caribbean coast, just east of Guabito.)
(* = less than 0.5 day)

Spring: March – May. As the ITCZ begins its return northward, spring marks the end of Panama's dry season. However, rainfall doesn't increase dramatically until May, especially in Panama City (see data on next page). Additionally, most locations have their minimum rainfall during the month of March (which in this particular seasonal grouping comes a month *after* the "dry" season). Compared with the winter values, mean cloudiness increases to 45–90 percent, with higher values in the mountains. While daily maximum temperatures are in the mid to high 80's (°F) along the coast, the maximum temperature averages in the 70°F – 79°F range in the mountains. Average minimum temperatures along the coast are in the mid 70's (°F), with 46°F – 60°F in the mountains. Average relative humidity is 75–80 percent. Precipitation gradually increases, especially noticeable at Panama City where the average of four precipitation days per month during March increases to 22 in May (see data on the following page). Thunderstorms also increase at Panama City, from one per month in March to 15 in May. Gale force winds, although slightly more frequent on the southwest coast, have an average frequency of only 1 percent.

Flying weather: Fair to good. Ceiling/visibility less than 5000 feet and/or 6 miles occurs 5–15 percent of the time along the southern coast, yet 15–40 percent along the northern coast and in the mountains. Similarly, ceiling/visibility less than 1500/3 occurs only 1–5 percent along the southern coast, compared to 10–20 percent along the northern coast and continental divide. Although ceiling/visibility less than 500/1 averages less than 1 percent, diurnal showers and thunderstorms lead to deteriorating conditions in the late afternoon and evening (see Appendix B for ceiling/visibility statistics for several stations).

Terminal weather:

Panama City/Torrijos International. Good. While ceiling/visibility less than 300/1 occurs only 1–2 percent of the time, the worst conditions occur in the morning near inland lakes and bays, and in the afternoon in the mountains. Thunderstorm frequency triples in May compared with March and April (USAFETAC, 1985).

Monthly temperature, precipitation, thunderstorms & twilight (USAFETAC, 1985):

PANAMA CITY/TORRIJOS INTERNATIONAL	MAR	APR	MAY
TEMPERATURE (°F)			
Absolute maximum	97	94	96
Mean maximum	90	90	88
Mean minimum	74	74	75
Absolute minimum	63	64	69
MEAN PRECIPITATION (INCHES)	0.3	2.7	8.8
MEAN NUMBER OF DAYS			
Precipitation	4	9	22
Thunderstorms	1	4	15
CIVIL TWILIGHT (15th of month)			
First light (local standard time)	0604	0548	0537
Last light (local standard time)	1850	1849	1901

CHANGUINOLA INTERNATIONAL #			
TEMPERATURE (°F)			
Absolute maximum	92	93	94
Mean maximum	88	88	89
Mean minimum	71	72	73
Absolute minimum	66	68	64
MEAN PRECIPITATION (INCHES)	5.7	7.2	8.4
MEAN NUMBER OF DAYS			
Precipitation	10	12	12
Thunderstorms	*	2	10

(#Changuinola is near the northwest Caribbean coast, just east of Guabito.)
(* = less than 0.5 day)

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